University of Alberta

The Economics of Agricultural Best Management Practices in the Lower Little Bow Watershed

by

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Abstract

In this research project, an economic cost/benefit analysis was performed for implementation of Best Management Practices (BMPs) by a large mixed farm in southern Alberta. The study was undertaken in order to better understand the private benefits and/or costs to a producer who introduces riparian habitat and water preservation and conservation practices onto their operation. The study was performed by modelling a farm representative of a large mixed crop and livestock operation in the Lower Little Bow Watershed in southern Alberta. The site was well suited for agricultural BMP analysis because of the wide range and intensities of agricultural activities associated with the operation.

The data collected was used in a Monte Carlo simulation analysis. For a base scenario and a set of BMP implementation scenarios, Net Present Values were calculated over a twenty year period. The overriding conclusion in this study is that best management practice implementation for riparian and water protection is costly to producers. Thus, producers may need to be provided with economic incentives in order to implement best management practices. The results of the study may be used as approximations of the size of incentive payments that may encourage producers to implement BMPs.

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Acronym Reference

AAFC – Agriculture and Agri-Food Canada
AAR – Average Accounting Return
AARD – Alberta Agriculture and Rural Development
ABGOV – Government of Alberta
ABP – Alberta Beef Producres
AFSC – Agriculture Financial Services Corporation
AIC – Akaike Information Criterion
AU – Animal Unit
AUM – Animal Unit Month
BCMAFF – British Columbia Ministry of Agriculture, Food and Fisheries
BMP – Best Management Practices
CPI – Consumer Price Index
CWT – One Hundred Weight
CAIS –Canadian Agricultural Income Support Program
EFP – Environmental Farm Plan
EG&S – Ecological Goods and Services
FAO –Food and Agriculture Organization of the United Nation
GWA – Government of Western Australia
GM – Gross Margin
GDD – Growing Degree Days
GS – Growing Season Precipitation
GMC – George Morris Centre
IRR – Internal Rate of Return
LLB – Lower Little Bow
MNCF – Modified Net Cash Flow
NEFPI – National Environmental Farm Plan Initiative
NCF – Net Cash Flow
NPV – Net Present Value
OLS – Ordinary Least Squares
OSW – Off-stream Watering
PBK – Payback Period
SIC – Schwarz Information Criterion
SUR – Seemingly Unrelated Regression
TSS – Total Suspended Solids
USDA – United States Department of Agriculture
WACC – Weighted Average Cost of Capital

Chapter 1 : Introduction

1.1 Background

The impacts of agriculture on water quality are diverse. Agriculture is both a cause and victim of water pollution (Ongley, 1996). Poor agricultural practices cause the discharge of pollutants and sediment to surface and/or groundwater. Reversely, polluted ground and/or surface water may contaminate crops and transmit disease to consumers. Overall, to stop the adverse effect of agriculture on water quality, appropriate management strategies must be taken so that subsequent uses of water for different purposes are not impaired (Ongley, 1996).

Bordering nearly every stream, lake, river and wetland is a riparian area. Roath and Kreuger (1982) classify riparian zones as areas adjacent to streams, lakes, and/or wet areas where plant communities are predominately influenced by their relationship with water. These forage rich areas are found between bodies of water and upland areas. They are a key contributor to water quality preservation and maintenance, providing protection from stream bank erosion, upland flood damage and the leaching and/or run-off of harmful substances. They provide fish and wildlife habitat and recharge groundwater. Considered one of the most productive types of ecosystems in the world, there are environmental and economic benefits in effectively managing riparian areas (AAFC, 2003). Economically, benefits come in the form of the rich forage that is able to sustain and supply livestock grazing and groundwater recharge that aids in the production of annual and perennial crops and helps to maintain livestock dugout and well water levels. Other benefits include the possibility of timber harvesting, trapping, tourism and recreation as well as real estate opportunities (AAFC, 2003).

It is widely recognized that there is excellent potential to benefit from using riparian areas in a number of ways. Agriculturally, the benefits have not gone unnoticed and producers try to take full advantage of these benefits whether through grazing potential or cropping the moisture rich and productive soil. Through time however, over-utilization of these productive areas has come at the expense of riparian vegetation loss, water quality loss, habitat loss, stream bank and channel damage and a number of others. Resultantly, the gradual loss of riparian vegetation and ecosystem health has reduced the otherwise consistent economic benefits from properly managing riparian areas (AAFC, 2003).

Producers have literally eroded this potential through intensive cropping practices such as cultivating land and planting crops up to the edge of creeks and streams removing important vegetation leading to higher incidences of erosion and chemical leaching (Ongley, 1996). Extensive livestock grazing has led to soil compaction, impairment of vegetative growth as well as physical damage to stream banks (Kaufman and Kreuger, 1984). Growing crops or grazing livestock too close to a natural body of water reduces bank stability and increases the risk of sediments, nutrients and pesticides being washed into the stream from the surrounding land. Hence, farmers need information on planning and managing riparian areas for the conditions on their farm (Vanderwel and Jedrych, 1997)

Traditional farming practices have just recently started to consider the proper management of riparian areas to minimize non-point pollution (Stillings et al., 2003). Environmental and producer organizations have increasingly become more concerned over the maintenance of these sites. This is supported by the emergence of numerous programs studying the effect of agriculture on riparian ecosystems and water quality. One such program is the Alberta Riparian Habitat Management Project (Cows and Fish). It has helped to increase the level of understanding of how improvements in grazing management can enhance the health and productivity of riparian areas while benefiting the producer and surrounding communities. These riparian management strategies to mitigate pollution have been referred to as Best Management Practices or Beneficial Management Practices (BMPs).

The benefits to the environment of best management practices and strategies have clearly been established (Platts and Wagstaff, 1994; Kaufman and Kreuger, 1984; Fitch and Adams, 1998; Agouridis et al., 2005). Economic benefits are also available to producers in using this forage rich environment as well (Miller, 2002). However, detailed economic costs and/or benefits to producers of conserving these areas have not been thoroughly defined (Fitch and Adams, 1998; Miller, 2002).

1.2 Economic Problem

The purpose of this study was to analyze the on-farm economic costs and benefits of implementing best management practices on a representative mixed farm in southern Alberta. The best management practices chosen and analyzed are aimed at riparian ecosystem and water quality preservation, maintenance and protection. The economic analysis was done to determine the direct costs and/or benefits to the producers of implementing BMPs for these purposes. In other words, is it economically feasible for a producer to implement BMPs for enhanced riparian management? If so, then what are sources of any economic benefits? If not, then what and in what form are the costs to the producer for introducing a best management practice? The information is not only useful to the producer, but to policy makers and/or legislators who are proactively researching the economic results of riparian management strategies. It should be noted that this study does not investigate the economic costs and/or benefits to society from riparian habitat and water quality management.

The farm modeled and analyzed is representative of a large cow/calf farm with crop production (i.e., mixed farm) found within the Lower Little Bow Watershed in southern Alberta. The surrounding geographical area has a large population base and is very agriculturally intensive, emphasizing the need for an adequate supply of fresh water. The Lower Little Bow Watershed is well suited for BMP analysis with its large agricultural base and the impact land use activities have on riparian habitats and stream and river water quality.

Using the representative characteristics for a farm in the aforementioned area, Monte Carlo simulation was performed to imitate cash flows over time for a net present value (NPV) analysis of best management practice implementation. Replicating cash flows to derive net present values is a capital budgeting technique that allows for easy comparisons between different best management practices. Various scenarios were modeled and then compared to the base situation where the farm does not have any BMPs in place. This comparison to a base or reference allowed for a straightforward analysis as to whether the BMP provided an economic benefit or cost. It also made it possible to find the source of the cost or benefit from implementation as all major and significant biophysical and economic relationships were modeled.

Along with advantages to modeling the biophysical and economic relationships that occur within the farm operation, relationships and influences external to the farm were included. These relationships contributed stochastic elements that were the main drivers behind the profitability of the farm. These stochastic components were crop prices, beef prices and weather in the form of growing season precipitation and growing degree days. Weather events influenced crop yields over time. The culmination of all the above allowed for a concise and detailed analysis of the economic impact of implementing best management practices on a large mixed farm in southern Alberta.

1.3 Organization of Study

Six chapters follow this introduction to the study. Chapter 2 provides an in-depth literature review of all aspects related to this study. This includes a brief outline of the agricultural industry in Alberta, an overview and description of riparian ecosystems followed by the impacts of various agricultural sectors on these riparian ecosystems and water. A thorough explanation of best management practices and the specific BMPs that are analyzed is included, followed by references to past and current initiatives that have been established to promote BMP implementation.

Chapter 3 provides a detailed overview of the characteristics of the geographical region in which the Lower Little Bow Watershed and the representative farm are located. This chapter is useful in building an understanding of the major agricultural activities in the area that impact riparian ecosystems. Furthermore, it helps to identify the structure and characteristics of the representative farm in terms of crop mix and rotation, livestock grazing capacity, etc. It also outlines the problems that have arisen in the area in terms of water quality reduction over time from agricultural sources and thus supporting the need for BMP implementation.

Chapter 4 provides a detailed discussion of the capital budgeting and net present value estimation used in BMP comparisons. This accompanies an in-depth overview of Monte Carlo simulation. This gives way to an explanation of the farm model structure that was developed to undertake the objectives of this study.

The fifth chapter provides a thorough and complete description of the simulation model and all its constituent parts that allow for a complete investigation of the economic questions proposed. All biophysical and economic relationships as well as the stochastic elements impacting these relationships are described in detail. All scenarios and sensitivities simulated are outlined and explained.

The final two chapters, Chapters 6 and 7, present the results of scenario and sensitivity simulations from BMP implementation, a discussion of results and the final conclusions and thoughts for future research drawn from the entire study.

Chapter 2 : Agriculture, the Environment and Best Management Practices

This chapter provides a background discussion to the present study. The main purpose is to introduce the agricultural industry in Alberta and some of its effects on the environment; more specifically, the effect of agriculture riparian habitats and water quality. This chapter includes an in depth definition of riparian ecosystems, and best management practices as well as providing an explanation of the BMPs that are used in this analysis. A brief summary is presented explaining the role of BMPs in the economic study of ecological goods and services (EG&S). Previous research presented in this chapter will allow for a deeper understanding of the background and the need for research and analysis in the area of environmentally friendly agriculture.

2.1 Agriculture in Alberta

This section briefly describes the major components of the agricultural sector in Alberta to illustrate the size and impact this sector has within the province. In 2005, Alberta farm cash receipts (FCR) totaled $7.9 billion, representing 21.4% of total Canadian FCR (AARD, 2006). Gross Domestic Product (GDP) from primary production sectors was approximately $4.4 billion in 2005, accounting for 2.0% of total GDP for the same year (ABGOV, 2007). This is small in comparison to the oil industry which accounted for 28.3% ($61.8 billion) of Alberta's 2005 GDP (ABGOV, 2007). However, the total area of farms in 2006 was approximately 22 million hectares out of a total land area of 66 million hectares. Agricultural activities make up one-third of Alberta's total land usage, indicating the potential significance of environmental sustainability issues within agriculture.

2.1.1 Alberta Beef

Beef is Alberta's number one agricultural commodity and the industry contributed approximately 40% of total FCR in 2005 (ABGOV, 2007). Alberta had the largest share of Canada's beef cattle population in 2005 with approximately 39% of the national population. Alberta also accounted for 63% of total Canadian beef slaughter (AARD, 2006). As of 2006, beef production occurred on more than 40% of Alberta farms

(Statistics Canada, 2006 Census of Agriculture). The beef industry is composed of three areas; cow/calf operations, backgrounding and feedlots. This study will incorporate the cow/calf and backgrounding aspect of the Alberta beef industry within the modeling framework and analysis.

2.1.1.1 Cow/Calf Operations

The first stage of the beef production process occurs on cow/calf farms. These farms raise steers and heifers to sell to backgrounding or feedlot operations. Heifers may be retained for herd expansion or to replace cull cows. According to the Alberta Beef Producers (ABP), there were 2.23 million breeding cows and heifers and cows in Alberta as of 2007 making up 39% of breeding herd in Canada. Cows usually produce one calf per year leading to an annual production schedule. Cows are traditionally bred between June and August, resulting in a calving season nine months later between February and April. Cows are suitable to be rebred approximately 85 days after calving (ABP, 2008). In this calving rotation, calves are weaned at a weight between 360 and 650 pounds after grazing on pasture between September and November (ABP, 2008). The weaning weights are dependent on beef breed, calf age and feed availability and conditions over grazing. These calves will then either be sold or heifers retained for herd replenishment and maintenance.

2.1.1.2 Backgrounding Operations

Backgrounding operations involve feeding a high forage diet to freshly weaned calves in order to increase their weight before they are sent to the feedlot to be finished. Alberta Beef Producers (2008) state that 50% of weaned calves go to backgrounding operations before entering the feedlot. The other 50% go directly to the feedlot from weaning. In this production enterprise, controlling costs is a very important element. Costs depend on animal rate of gain so the management of feed production and quality is essential (AARD, 2004).

2.1.1.3 Feedlot Operations

The feedlot is the final stage of the beef production cycle. Calves from cow/calf farms or feeder cattle from backgrounding operations are bought by feedlot owners who then 'finish' the cattle to a desired weight and degree of marbling. Marbling is a term describing streaks of fat running through lean beef cuts that enhance the quality of tenderness, juiciness and flavour. Most producers try to achieve the highest marbling possible to get the highest returns. Of all the animals produced in Alberta, over 90% reach a grade of A, AA, AAA or PRIME which are the most desired categories in the Canadian meat grading system (ABP, 2008). There are 4000 feedlots in Alberta with various production capacities ranging from a few hundred finishing animals to 40,000. One hundred of the largest feedlots produce 75% of the finished cattle in Alberta (ABP, 2008). After finishing, cattle are sent to slaughter facilities. Alberta currently processes more than 52,000 head of finished cattle per week.

2.1.2 Alberta Crops and Forage

Crop production, including barley, canola, flax, oats, rye and wheat, made up 25% or $1.96 billion of total Alberta FCR in 2006 (ABGOV, 2007). According to the 2006 Statistics Canada Census of Agriculture, the total area under crop production in the province was approximately 9.6 million hectares or 15% of Alberta's total land area. Crops made up 2.5% of Alberta's major exports in 2006.

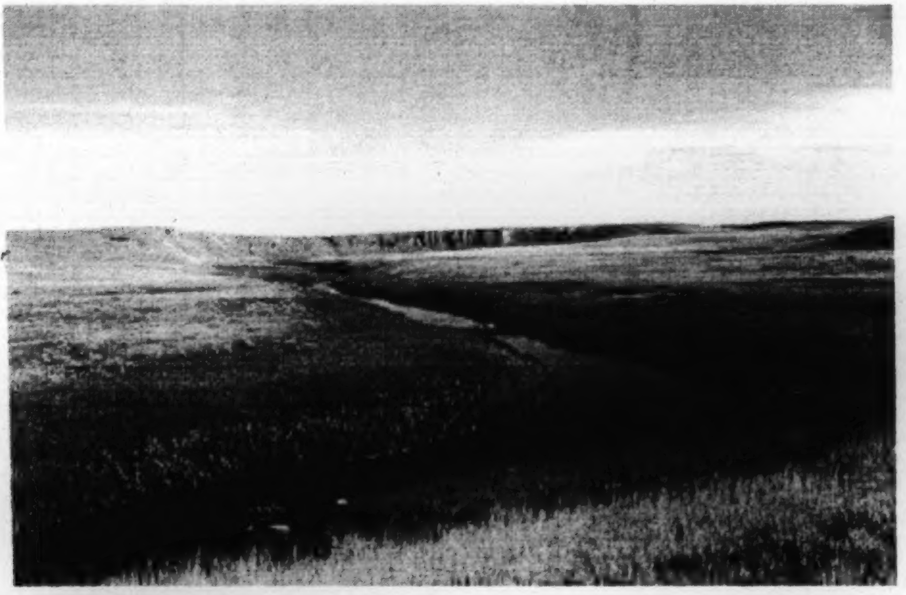
To accompany the large amount of beef production, a significant supply of feeds in the form of pasture, hay and silage are needed. In 2006, Alberta had approximately 2.37 million, 2.4 million and 28,494 hectares of land in pasture, hay and silage, respectively, with production from these enterprises being available for livestock feed use.

2.2 Riparian Ecosystems

2.2.1 What is a Riparian Ecosystem?

The word 'riparian' is derived from the Latin word 'riparius' meaning "of or belonging to the bank of a river". It is presently termed as a biotic community on the shores of lakes, streams and other natural bodies of water (Naiman and Decamps, 1997). In other words, the zones between bodies of water and upland environments are known as riparian areas, zones or ecosystems (AAFC, 2003). These include stream banks, creeks, lakeshores and wetland fringes. The presence of free unbound water leads to unique plant communities and this vegetative environment provides lush and productive forage for grazing livestock as well as habitats for various fish and other wildlife (Fitch and Adams, 1998). A healthy riparian ecosystem stabilizes stream banks, determines bank morphology and reduces stream bank damage due to debris and animal grazing and is the most biologically diverse and productive of all temperate, terrestrial ecosystems (Kaufmann and Kreuger, 1984).

Figure 2.1 - An illustration of a riparian ecosystem



Source: AAFC (2003)

2.2.2 Why Protect Riparian Ecosystems?

"Riparian areas are too important, too productive and too valuable to go unrecognized and unmanaged" (Fitch et al., 2003, p. 4). Bordering nearly every stream, lake river and wetland is a riparian area and the alteration or removal of this environment has a large impact. This impact is felt not only in terms of hydrologic, plant and wildlife subsystems, but also recreational opportunities, aesthetics and other characteristics valued by humans (NRC, 2002). Riparian area conservation and/or restoration is a critical success factor in the protection of water quality, wetlands, threatened and endangered species and the reduction of flood damage, none more important than the protection of water quality (NRC, 2002).

According to the Food and Agriculture Organization of the United Nations (FAO), agriculture is the largest user of fresh water sources using 70% of all surface water supplies. The following are principal environmental and public health aspects of freshwater quality problems highlighted by the FAO:

- Human deaths from water-borne diseases (five million annually).
- Ecosystem dysfunction and loss of biodiversity.
- Contamination of marine ecosystems from land-based activities.
- Contamination of groundwater resources.
- Global contamination by persistent organic pollutants.

Due to pollution, dwindling supplies of good-quality freshwater combined with the world's ever-increasing demand for fresh water, countries must adopt a holistic approach to water resource management (Ongley, 1996). This holistic approach involves identifying all the sources of water pollution from point source and non-point source polluters. Point source pollution is a single identifiable source of pollution such as an oil refinery wastewater discharge outlet in to a stream or river. Non-point source polluters are harder to recognize and can include agricultural activities. Pollutants detected in a water source such as a stream, river or lake, may have come from a wide range of sources. These agricultural sources include leaching of fertilizer and pesticides, livestock defecation, leaking of machinery oil and fuels as described in the previous chapter. In 1991, the National Research Council reported that 50% of non-point pollution came from agricultural sources.

Even though riparian areas make up a small percentage of a watershed, they represent an extremely important part of the landscape (Elmore and Beschta, 1987). In this study, riparian ecosystems are the area of focus. Bellows (2003) describes riparian areas as providing:

- Water quality protection
- Structural support for stream banks
- Water capture, storage and flood control
- Stabilization of water flows in streams and rivers
- Habitat for aquatic and terrestrial wildlife
- Aesthetic and recreational benefits

Decades of various land use practices have degraded these areas leading to damaged environmental conditions and a multiplicity of social costs (Bellows, 2003).

Public interest has been at the forefront of riparian conservation (Dosskey, 1998). Public policy in the United States has begun to focus attention on riparian management and conservation with the Riparian-Wetland Initiative in the 1990's, Grazing Lands Conservation Initiative for Private Grazing Lands and the National Conservation Buffers Initiative (Dosskey, 1998). In Canada, this study is part of a national project known as the Watershed Evaluation of Beneficial Management Practice (WEBs) which studies seven sites across the country to understand the biophysical and economic impacts of BMP implementation for riparian conservation. Further discussion of riparian management studies is provided in section 2.5.

2.2.3 Effect of Livestock on Riparian Ecosystems

Riparian areas have always been a rich source of forage and a reliable water source for livestock. Cattle make a disproportionately higher use of riparian areas relative to uplands because of the rich availability of forage and the short distance to water. Reid and Pickford (1946) state that one acre of mountain riparian habitat has the potential grazing capacity of 10-15 acres of forested range. Research on the effects of agriculture on stream ecosystems and water quality has been well documented. Kaufman and Kreuger (1984) provide a review of the agricultural impacts on riparian ecosystems, reporting that livestock and cropping mismanagement results in the degradation of riparian environments. Riparian overgrazing from livestock can lead to soil compaction, impairment of plant species vigour and physical damage to channels and banks (Fitch and Adams, 1998). Introducing livestock for as little as 6 weeks into a riparian area that has previously been rested for 4 years has been shown to cause erosion of banks into streams (Kaufmann and Kreuger, 1984). Stream bank degradation may lead to a decrease in water quality due to increased chemical and fecal runoff. As riparian ecosystem health is critical to wildlife and plant diversity as well as to water quality, Platts and Wagstaff (1984) indicate that riparian ecosystems should be identified and managed separately from upland ecosystems.

Belsky et al. (1999) in the Journal of Soil and Water Conservation summarized the major effects of livestock activity on riparian ecosystems and streams in the western United States. They reported that according to the United States Department of the Interior, 80% of streams and rivers in the arid west have been damaged by grazing livestock. The paper stressed the serious problems and consequences of grazing on riparian environments with reference to many riparian studies. These studies included the damaging effects of cattle on vegetative cover and biomass from trampling, plant succession problems from late season grazing and the decline in riparian animal species from this disappearance of riparian vegetation. Increased bacterial counts and higher water temperatures from cattle defecation negatively affected fish spawning and survival. A search of all studies and peer-reviewed publications on livestock impacts on riparian ecosystems and water quality did not uncover any position that reported a positive impact of cattle in these areas. Many remedies to repairing riparian ecosystem health were proposed but most concluded that a long term period of rest from grazing was the most beneficial.

Larsen et al. (1994) studied the benefits to water quality when cattle manure is deposited away from streams. Organisms from manure can enter waterways directly as animals spend time along banks or in streams. Water runoff from rainfall or snowmelt can also deposit manure into stream systems. Higher concentrations of these organisms due to large herd sizes or the location of fecal matter deposition increase the possible pathogen levels thereby diminishing water quality. Laboratory experiments tested the trace of fecal coliform bacteria in water samples where fecal matter was deposited at different distances from a body of water. Tests were performed under various rainfalls, ambient temperatures, stream bank slopes, and soil types for various infiltration rates. Results indicated that the farther away the fecal matter is deposited, the less the impact on water quality.

Clary (1999) conducted a 10 year riparian grazing study in central Idaho after conflicts emerged between cattle grazers and salmon fisheries. Pastures were developed to study the effect of no-grazing, light grazing (20-25% utilization) and medium grazing (30-35% utilization) on riparian environments. These sites were originally heavily grazed sites. Under all three treatments, stream stability increased, stream channels narrowed and plant species richness increased on stream banks. All treatments decreased substrate embeddedness, leading to an increase in stream sediment transport efficiency. In fish spawning areas, the amount of stream substrate and water flows are key factors to fish cover and survival.

Hoover et al. (2001) studied the short term effects of cattle exclusion on riparian ecosystems in southeastern Kansas. The study was conducted over a two year period on riparian habitats over an area of 5,263 hectares. Three sites of varying size were fenced off to cattle (ungrazed) and three other sites of similar size, mean tree density and mean stream length were grazed in similar geographical areas. At the end of the two year period, riparian vegetation differed between the grazed and ungrazed sites. Grass cover, herbaceous cover, and vegetation height was greater in the ungrazed sites. Vegetative species such as Virginia wild rye and tall fescue benefitted from cattle exclusion. Similar results have been found in many other studies examining effects of livestock on riparian habitats (e.g., Fleischner, 1994; Green and Kaufmann, 1995; Clark, 1998).

2.2.4 Effect of Cropping on Riparian Ecosystems

According to Vanderwel and Jedrych (1997), management practices used in upland areas have a significant effect on sediment discharge on streams. Furthermore, cropping activities that are too close to bodies of water reduce bank stability and increase the risk of sediments, nutrients and pesticides being washed into the stream from the surrounding land. Table 2.1 summarizes the effect of cropping activities on surface and groundwater.

Table 2.1 - Agricultural impacts on water quality

Agricultural Activity	Impact	
	Surface Water	Ground Water
Tillage/ Plowing	**Sediment/turbidity**: sediments carry phosphorus and pesticides adsorbed to sediment particles; **siltation** of river beds and loss of habitat, spawning ground, etc	
Fertilizing	Runoff of nutrients, especially phosphorus, leading to eutrophication causing taste and odour in public water supply, excess algae growth leading to deoxygenation of water and fish kills.	Leaching of nitrate to groundwater; excessive levels are a threat to public health.
Pesticides	Runoff of pesticides leads to contamination of surface water and biota; dysfunction of ecological system in surface waters by loss of top predators due to growth inhibition and reproductive failure; public health impacts from eating contaminated fish. Pesticides are carried as dust by wind over very long distances and contaminate aquatic systems 1000s of miles away (e.g. tropical/subtropical pesticides found in Arctic mammals).	Some pesticides may leach into groundwater causing human health problems from contaminated wells.
Irrigation	Runoff of salts leading to salinization of surface waters; runoff of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts.	Enrichment of groundwater with salts, nutrients (especially nitrate).

Source: Ongley (1996)

2.3 Best Management Practices

2.3.1 What is a Best Management Practice?

Best Management Practices (BMPs) are pollution preventing farming methods which ensure the minimization of environmental risks without sacrificing economic productivity (AAFC, 2000). BMPs can contribute positively to the sustainability of agriculture by requiring the maintenance and care of water, soil and air quality (AAFC, 2000). This can be made possible with the implementation of strategies to reduce sediment and nutrient runoff into water, control pests, and properly store chemicals. Some examples of BMPs include fencing riparian areas, off-stream watering for livestock, buffer strips, manure management and grazing/crop rotation systems. In this study, BMPs are studied and modeled in an effort to understand the economic costs and/or benefits of on-farm implementation of BMPs to preserve and maintain riparian ecosystems and water quality.

BMPs have been implemented in sectors besides agriculture or in areas without water quality concerns. For example, the U.S. Bureau of Land Management has implemented BMPs within its oil and gas industry to ensure that energy development is conducted in an "environmentally responsible manner". Also, the California Oak Mortality Task Force implemented BMPs to eliminate diseases caused by Phytophthora ramorum, a fungus that causes problems in horticultural nurseries.

2.3.2 Ecological Goods and Services and Best Management Practices

The field of ecological economics has observed an increase in the study of the valuation of ecosystem functions, goods and services over the last few decades (Groot et al., 2002). Costanza et al. (1997) describe *Ecological Good and Services (EG&S)* as the benefits that humans derive from ecosystem services, either directly or indirectly. Agricultural producers maintain and manage land for food production and concurrently provide EG&S through the preservation of healthy ecosystems. Examples of ecological goods include clean air and abundant fresh water. Ecological services include purification of air and water, maintenance of biodiversity, pollination of crops and natural vegetation.

Best management practices are the means by which the value of ecological goods and services can be increased. (Boxall, 2008) A list of nationally recognized BMP's with corresponding EG&S are listed in Table 2.2. These BMPs are a product of National Farm Stewardship and Greencover Canada Programs described later in this chapter. The table provides clarification with respect to the difference between a BMP and an EG&S. In this study, BMPs are implemented for the purpose of improving water quality. For example, riparian fencing to remove animals from waterways is a BMP which, in turn, reduces the risk of pathogens infecting animals and human. This cleaner water represents an increase in EG&S.

Costanza et al. (1997) argue that because of the difficulty in quantifying ecosystem services, EG&S are given little weight in policy decisions. It is not difficult to understand that human activities have altered earth's ecosystems and that preserving species diversity and ecosystem functionality will require increasing public and/or private involvement (Vistousek et al, 1997).

As early as 1969, Helliwell recognized the production, educational and recreational benefits of wildlife in ecosystems. He attempted to devise a system to compare wildlife resources and put a monetary value on the entire system for cost/benefit analysis of conservation of natural ecosystems. However, to date, there is a lack of information to evaluate the public and/or private value of the environmental benefits of BMP adoption (Webber and Boxall, 2008) and landowners' supply of EG&S enjoyed by society. The continuous change of ecosystems, consumer uncertainty about EG&S benefits and the unknown impacts of current consumption on future availability of EG&S make it difficult to establish a market value for perceived benefits. Webber and Boxall (2008) make this same case about the public and private values of BMP adoption. There are problems in defining the environmental benefits of adoption as it is difficult to assess the level of environmental change.

This study only looks at the on-farm costs and benefits of the implementation of BMP`s and does not consider their impact on EG&S. The possible adoption of BMPs by producers will be hindered without an evaluation of direct on-farm costs/benefits.

Table 2.2 – Summary of the relationship between Best Management Practices and ecological goods and services in livestock and crop production[1]

Production Practice	General Best Management Practice (NFSP recognized)	Site Specific BMP	Ecological Goods & Service[2]
Grazing Management	- Grazing Management Planning - Riparian Area Management - Riparian Health Assessment	- Buffer Strips - Strategic Fencing - Offsite Watering - Re-Establishment of Native Rangeland	- Erosion Control and Sediment Retention - Soil Formation - Nutrient Cycling - Water Treatment - Water Regulation - Water Supply - Food Production - Disturbance Regulation - Recreation - Refugia (Animal Habitat)
Backgrounding/Feedlot	- Relocate Livestock Confinement Facilities - Farmyard Runoff Control	- Relocation - Buffer Strips - Constructed Wetlands	
Manure Management	- Nutrient Management Planning - Manure Storage Handling - Manure Treatment - Manure Land Application	- Increased Storage - Increased Protection - Composting - Equipment Modification	
Winter Management	- Wintering Site Management	- Shelterbelts and Windbreaks - Offsite Watering	
Tillage	- Soil Erosion Control Planning - Improved Cropping Systems - Winter Cover Crops - Land Management for Soils at Risk - Irrigation Management Planning	- Equipment Modification - Contour Farming - Mulching - Land Retirement - Zero Till	- Erosion Control and Sediment Retention - Soil Formation - Nutrient Cycling - Water Treatment - Water Regulation - Water Supply - Food Production - Disturbance Regulation - Biological Control - Genetic Resources - Recreation - Refugia (Animal Habitat)
Fertilization/Seeding	- Nutrient Management Planning - Improved Cropping Systems	- Equipment Modification - Precision Farming	
Pesticide Application	- Integrated Pest Management Planning - Improved Pest Management	- Equipment Modification - Biological Control Agents	
Harvest and Residue Management	- Preventing Wildlife Damage - Product and Waste Management	- Increased Storage - Increased Protection	

[1] Source: Webber and Boxall (2008)

[2] Source: Costanza et al. (1997)

2.4 Best Management Practices of Interest

This study examines the economic implications of implementing BMPs that have been identified by expert opinion as being relevant for the area under consideration. These include off-stream watering for livestock, fencing riparian areas (i.e., exclusion fencing), buffer strips and converting cropland to permanent cover. It should be noted that producers may consider other potential BMPs depending on the type of agricultural production and the environmental quality attribute of interest. Table 2.2 provides other examples of BMPs.

2.4.1 Off-Stream Watering

Water resources for cattle most often come from dugouts, ponds and wells (Willms et al., 2002). Water channels, including rivers, streams and/or creeks on any grazing land, are also commonly used. Most of the fecal contamination in these water channels occurs from animals defecating directly into the water (Miner et al., 1992). This increases fecal coliform bacteria counts, reducing water quality. Cattle drinking directly from these waterways have an adverse effect on the health of riparian ecosystems. Off-stream watering is an effective way of maintaining riparian ecosystems and water quality while sustaining or even improving animal performance[1].

Miner et al. (1992) explain that by minimizing the time spent in waterways, direct fecal contamination will be significantly reduced. They studied the behavior of cattle when exposed to an off-stream watering site in winter feeding conditions. In this case a watertank was placed 90 metres away from the stream. Results showed that once the cattle were accustomed to the tank, time spent by or in the stream decreased by 90%. One possible reason for this behavioural change was the ease of access to the tank. The ground was dry, level and firm around the tank which may have been more attractive than the steep and muddy access to the stream. Similar studies performed by Smith et al. (1992), Clawson (1993) and Godwin and Miner (1996) confirm the effectiveness of off-stream watering sites in terms of decreasing the time spent in waterways.

Porath et al. (1997) implemented off-stream watering sites and trace minerals to reduce grazing pressure on riparian areas. The hypothesis tested was that off-stream watering sites and trace minerals could influence cattle distribution, performance, and behaviour while grazing riparian meadows and uplands. Through visual observation, aerial photos and other devices, distinct differences in cattle distribution were observed. Early in the grazing season, cattle with off-stream sites available spent more time upland compared to cattle that were forced to use the stream as a water source. However, towards the end of the grazing season this difference dwindled. Cow and calf weight gains were influenced by the presence of off-stream watering and trace mineral sites. Over the 42-day test grazing period, calves with off-stream watering availability gained 11.5 kg over the grazing season or 0.14kg/day more than those cows and calves that used the stream as a water source. This accumulated to a 13% increase in weight over the grazing season. This was a result of better cattle distribution and grazing patterns whereby cattle tended to graze more uniformly over off stream pastures and a healthier water source. There was no significant difference in fecal deposits along the stream bank. Overall, results showed a decrease in riparian grazing pressure with the existence of off-stream watering sites.

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[1] A list of off-stream watering systems is found in Appendix A.

A study conducted by Sheffield et al. (1997) studied the effectiveness of off-stream watering sites in reducing cattle impacts on stream bank erosion. Observations confirmed a 92% decrease in the amount of time that cattle drank from a stream when an off-stream watering site was available. Clawson (1993) also reported an 81% reduction in the amount of time cattle drank from a stream when an off-stream source was available. Also reported was a significant decrease in stream bank erosion when an off-stream watering site was introduced. There was a 77% decrease in the amount of stream bank loss. Total suspended solids (TSS) were reduced by 89%, supporting the argument that off-stream watering sources reduce the amount of TSS found in waterways. A reduction in fecal coliforms and streptococci of 51% and 77%, respectively, was also observed in the waterways.

Stillings et al. (2003) evaluated the economic and ecological impact of off-stream watering site establishment on riparian areas. A bioeconomic linear programming model for a 300 head cow/calf operation was developed to analyze the economic impact of grazing management strategies. The analysis focused on comparing the optimal operating returns of the ranch with and without off-stream watering and trace mineral distribution in upland areas. The objective function maximized the total gross margin over the planning horizon subject to input costs, cow/calf herd dynamics in the farm and forage availability. The model calculated the economic response to different riparian protection levels. At various levels, providing an off-stream watering source and trace minerals had a positive impact on net returns. An increased distribution of livestock was observed which increased upland forage consumption, compensating for the loss of riparian grazing. Calf weights increased with improved pasture utilization which impacted gross margins at the end of the year. In total, expected net annual returns from cattle responses to off-stream watering sites and mineral distribution increased between $4,000 and $11,000 depending on cattle prices and precipitation levels.

Willms et al. (2002) conducted a study similar to the previously mentioned studies in southwestern Alberta to examine the effects of water source on cattle production and behaviour. A number of cattle paddocks were established with different water treatments, including clean water delivered through a trough, pond water delivered through a trough, or direct access to pond water. Trials were repeated for three to six years and observations were made on cattle weight gains and activity budgets. Calves who had cows drinking fresh water gained a statistically significant 9% more than those calves whose mothers drank pond water, either directly or indirectly. Yearling heifers with access to fresh water gained 23% more than those heifers subject to pond water. With respect to cattle behaviour, cattle that had access to fresh water spent more time grazing and less time resting than the animals that drank pond water.

2.4.2 Fencing Riparian Areas

Fencing of riparian areas, also known as controlled access fencing or cattle exclusion, is the construction of a physical barrier between riparian habitats and range or cropland. Most often this is done using electric or barbed wire fencing. Other types of fencing include reduced access fencing and limited point access fencing. Reduced access fencing allows a small opening that still permits livestock to drink or cross the waterway. Limited point access fencing allows livestock to drink from waterway, but not cross the waterway.

Platts and Wagstaff (1984) performed a literature review of the effects of exclusion fencing and studied the viability of fencing riparian habitats. They reviewed a number of studies which concluded that exclusion fencing is highly beneficial to riparian habitats and fish populations within and around waterways. However, even though there are positive impacts from exclusion fencing, it may not always be a viable solution. Platts and Wagstaff (1984) estimated a cost of $6000US per stream mile, maintenance costs of $60-$200US, and approximately 12 animal unit months (AUM) lost per mile of stream fenced. Twelve AUMs translates into 12,000 pounds of dry matter forage per fenced stream mile. Due to these high costs, exclusion fencing should only be considered when all other options have been investigated (BCMAFF, 2003)

Historically, riparian fencing has been used extensively to promote riparian area protection. However, the existence of an off-stream watering source has proved to be a very useful alternative to exclusion fencing (McIver, 2004). The studies in the previous section observing improved upland grazing provide enough evidence to support this.

2.4.3 Buffer Strips

Buffer strips, also known as streamside management zones, stream protection zones, riparian management areas or filter strips, are areas of land adjacent to waterbodies maintained in permanent vegetation in order to control pollutants and environmental problems (USDA, 2000). They provide benefits such as erosion prevention through trapping sediment and nutrient runoff, wildlife habitat improvement and improved farming safety (USDA, 2000). Dosskey (1998) explains that both private and public interests are able to benefit from healthy, perennial buffers. Increased forage production protected from livestock increases wildlife habitat, resulting in better game hunting and fishing opportunities. Some public benefits given by Dosskey (1998) include cleaner water, increased habitats for at-risk fish and wildlife, the promotion of bedload deposition and a higher water table.

Rein (1999) evaluated the environmental costs and benefits of implementing a vegetative buffer strip to protect water quality, soil fertility and the economic interests in an erosion prone watershed. Ecological benefits were quantified to calculate the cost savings of decreased yearly erosion protection. Non-quantifiable benefits to the watershed included the emergence of beneficial insects that were removed from the area when soils was converted to cropping. The existence of a buffer strip increased ground water recharge as erosion decreased. Economic and public interests to implementing a buffer strip included the benefits of cleaner drinking water for the watershed as a function of cost savings from households not having to invest in water cleaning systems. The value of buffer strips on recreation and ecotourism was quantified to be $1,000,000 per year in the long run. The watershed studied was a large visitor attraction and uncontrolled erosion and nutrient deposition were significant threats to the site. The study includes more benefits to the buffer strip implementation and Rein makes recommendations to encourage a BMP like buffer strips to become common practice. These recommendations require the grower or producer to bear the initial economic burden but develop ways for society to share the costs dependant on government legislation or federally funded programs.

Yang and Weersink (2004) examined the cost effectiveness of establishing riparian buffers through land retirement within watersheds in Ontario. An integrated modeling framework, using economic, hydrologic and GIS models was used to determine costs of different levels of sediment abatement. A 10 metre wide buffer with a 30% sediment reduction in waterway sediment build-up came at a cost exceeding $58,000. The economic cost to establish the buffer totalled $27,524 and the opportunity cost of forgone crop returns totalled $31,468.

2.4.4 Permanent Cover

Permanent cover is a BMP that involves using cover crops such as alfalfa and/or a no-till or conservation tilling system. Conservation tilling refers to establishing crops in previous crops' residues left on the soil surface (Sullivan, 2003). Benefits of conservation tillage include improved water conservation and reduced soil erosion (Sullivan, 2003).

The use of soil conservation practices has been increasing in Canada over the last few decades as producers have shifted from conventional tillage practices to production practices that improve soil quality (Boehm et al., 2004). Along with no-till, other conservation production practices are reducing summerfallow frequency, complementary and rotational grazing systems and perennial crop production. Boehm et al. (2004)

proposed that one of the largest benefits to these practices is increased carbon sequestration which is the process of removing carbon dioxide from the atmosphere. The study concluded that the conversion from annual crops to permanent cover was the largest enhancer of carbon sequestration over the adoption of no-till practices and reducing summerfallow frequency. This increase in carbon sequestration was a result of the reduction of soil disturbance and organic matter decomposition and increasing the plant biomass added to the soil.

Vanderwel and Jedrych (1997) compared different management strategies in terms of their ability to reduce sediment delivery to streams. Three upland management strategies were simulated on a hypothetical 60 hectare watershed with a soil type representative of that in central Alberta. The three crop rotations simulated were: wheat-wheat-canola-fallow (W-W-C-F); wheat-wheat-canola-barley (W-W-C-B); and wheat-wheat-canola-alfalfa- alfalfa- alfalfa- alfalfa (W-W-C-A-A-A-A). All rotations used conservation tillage. Sediment leaving the watershed was reduced by 61% (12.89t/ha/yr) when the crop rotation changed from W-W-C-F to W-W-C-B. This change was even greater, 74% (15.71t/ha/yr), when the rotation changed from W-W-C-F to W-W-C-A-A-A-A.

In this study, permanent cover is defined as the conversion of cropland near or on riparian areas to perennial crops including alfalfa hay, grass hay or and alfalfa/grass mix. The producer then has the option to harvest this forage and allow livestock the opportunity to graze it. The results of the above study support this BMP as it shows that applying a perennial forage crop reduces sediment loss.

However, the conversion of acreage from cash crops to forage may come at the expense of income. Held and Zink (1982) used a linear programming model to determine farm income variability from changing the cropping rotation in a mixed enterprise operation. Farm income as well as income variability decreased as acreage was converted from cash crops including sugar beets and beans to low income, low risk forage crops including alfalfa. The possibility of reducing producer income through the implementation of BMPs for riparian health and water quality conservation lends itself to the need for an economic cost/benefits analysis of any BMP implementation.

2.5 Implementation and Assessment of Best Management Practices

2.5.1 What has been done to implement BMP's?

Strategies to protect riparian areas were in place long before the definition of best management practices came into existence. Examples exist in the literature of studies that have researched and developed strategies to mitigate damage to riparian areas. Fitch and Adams (1998) developed strategies suitable for southern Alberta. These included season long grazing, livestock distribution, grazing systems, forage utilization and other special practices such as rest-rotation grazing and corridor fencing. However, these recommendations may prove to be economically infeasible leading to the discussion of how to provide the maximum benefits to all users of this valuable ecosystem (Platts and Wagstaff, 1984).

In 1992, a partnership between the Alberta Cattle Commission, Trout Unlimited Canada, the Canadian Cattlemen's Association, Alberta Environmental Protection, Alberta Agriculture, Food and Rural Development and Fisheries and Oceans Canada worked to produce the "Cows and Fish" project to provide an understanding between livestock grazing and riparian health and dynamics (Fitch and Adams, 1998). The project analyzed BMPs and riparian area grazing strategies by developing demonstration sites on southern Alberta ranches. Workshops were conducted for livestock producers to convey the message of riparian management through the use of BMPs. Under the Cows and Fish Project, the Alberta Riparian Habitat Management Society has published a number of editions of *Caring for the Green Zone: Riparian Areas and Grazing Management*. The goal of the partnership is to improve riparian health through community based action utilizing awareness and education to promote the understanding and appreciation of riparian areas. Since 1992, the Cows and Fish program has delivered its message to over 22,000 people across Alberta and western Canada through presentations, field days and workshops.

In 1999, the Florida Cattlemen's Association started a program named *Water Quality Best Management Practices for Cow/Calf Operations in Florida*. A program manual was sent out to producers on more than 6 million acres of pastureland to promote the protection of the integrity of water bodies while protecting producer interests. The manual introduced the concept of recording farming activities that may affect ground or surface water and then implement strategies to mitigate these effects.

More recently, Alberta Agriculture and Rural Development in partnership with the Alberta Beef Producers developed a manual for Alberta Cow/Calf Producers to raise awareness of BMPs. Created to provide cow/calf producers with various BMP options, *Beneficial Management Practices: Environmental Manual for Alberta Cow/Calf Producers* stresses the importance of making sure the agriculture industry is aware of public opinion on environmental care.

At a national level, the Government of Canada's National Environmental Farm Planning Initiative (NEFPI) encourages producers to adopt BMPs through financial and technical assistance to address identified environmental risks. The objectives of NEFPI are to aid producers in developing and implementing environmental farm plans (EFP's) and include:

- helping the agriculture sector better identify its impacts on the environment,
- promoting the growth of stewardship activities within the agriculture industry.

The NEFPI also supports the environmental objectives of the federal-provincial-territorial Agricultural Policy Framework by:

- assuring Canadians that agricultural resources are being managed in a sustainable fashion,
- helping to brand Canada in the global market as a source of safe, high-quality food produced in an environmentally friendly fashion.

Once an EFP is produced, producers are eligible to receive financial and technical assistance in the implementation of one or more BMPs outlined by the National Farm Stewardship Program (NFSP). The NFSP encourages adoption of a number of BMPs by providing financial incentives to producers. See Table 2.2 for a list of these BMPs.

2.5.2 BMP Implementation Programs Results?

In 1994, The Manitoba Habitat Heritage Corporation (MHHC) implemented the Green Banks Program to enhance the riparian habitat associated with livestock operations. The program introduced fencing riparian areas, buffer zones, paddock grazing and watering systems for livestock on a cost-shared basis. Cooperating producers were surveyed about the effectiveness of the program and results were positive. All respondents rated projects as being "satisfactory" to "excellent" and 96% would recommend their approach to friends and neighbours. (Sopuck, undated)

The Department of Agricultural Economics and Farm Management at the University of Manitoba conducted an economic evaluation of implemented BMP systems on a farm plot along the Bird-Trail River in western Manitoba. Results included a cow per acre net weight gain of 53.8 pounds for an economic gain of $50.50/year/cow within a 70 cow herd from the implementation of off-stream watering sites (Chorney and Josephson, 2000). The initial investment of $1,800 for implementation provided a net present value of $23,029 over 10 years at a 7% discount rate (Chorney, 1998). To support these results, 88% of respondents to a producer survey who implemented grazing and riparian management practices reported a greater than average animal weight gain, greater pasture forage quantity and quality, and increased overall operational net returns. Environmentally, 68% and 70% of respondents observed improvements in water quality and better cover for wildlife, respectively.

In 2007, The George Morris Centre (GMC) produced *An Economic Evaluation of Best Management Practices for Crop Nutrients in Canadian Agriculture*. Producers across the country were surveyed to obtain data to estimate the economic costs and benefits of implementing BMPs. The main objective of this research was to determine farm prosperity before and after BMP implementation and to evaluate the incentives needed for producers to start implementing BMPs. Representative farm models were developed for Alberta, Saskatchewan, Manitoba, Ontario, Quebec and Prince Edward Island using specific crop rotations and crop enterprise budgets from the respective provincial governments.

With regards to Alberta, GMC assumed two soil zones; black and brown. Crop rotations were based on an on-farm distribution of seeded crops; 40% spring wheat, 30% canola, 20% barley and 10% peas in the black soil zone and 70% wheat, 15% lentils and 15% barley in the brown soil zone. Also, the size of the farm was assumed constant as crop enterprise budgets available were based on per acre data. In Alberta, this size was assumed to be 1358 acres, which was the mean size of surveyed farms. The types of BMPs chosen for each province were based upon survey data performed by Ipsos Reid, a national market research company. A BMP was chosen if it met the following criteria (GMC, 2007):

- it was currently not in use in the area but increased knowledge of the BMP would foster adoption
- producer interest was evident from survey data
- data from Ipsos Reid were available for use in evaluation

A BMP was not selected for an area if it was currently in use and data on the costs and benefits of implementing the BMP were readily available.

The representative farm model was simulated with and without BMP implementation where final results were expressed as farm profitability based upon expected net revenue (ENR) or contribution margin. BMP adoption was supported and justified if the ENR with the BMP in place was greater than the ENR of the base model where no BMP was in place. This modeling technique is similar to the approach to be used in the current analysis as described later in Chapter 5.

BMPs chosen for Alberta's brown soil zone were soil testing, minimum tillage and nutrient management planning (NMP). Soil testing consists of estimating the fertility of the soil for nutrient uptake and minimum tillage is the reduction of the number of tillage passes which does not turn the soil over leaving crop residues at the surface to help control erosion. The principles of nutrient management planning include the application of fertilizer only when there is a deficiency in the soil to achieve a maximum yield assuring cost effectiveness for the producer; there should be no excess nutrients once the crop has satisfied its needs (AAFC, 2000-a).

BMPs chosen for Alberta's black soil zone were variable rate fertilization (VRF), nutrient management planning and buffer strips. VRF is a technique used in precision farming systems where a field is divided into subunits and these subunits are individually soil tested. Each unit receives a separate fertilizer recommendation based upon soil test results.

Results of the BMP choices and subsequent simulation for Alberta's brown soil zone showed an increase in ENR with BMP implementation when compared to the base model. On a whole farm basis, soil testing, minimum tillage and NMP increased ENR by18.9%, 33.7% and 32.6% respectively. In Alberta's Black soil zone, VRF and NMP provided an increase in ENR (52.7% and 77.9%, respectively) but buffer strips decreased

ENR (-10.1%). The loss due to buffer strips is likely due to the reduction in farm production with the conversion of cropland to buffer vegetation (Yang and Weersink, 2004).

2.6 Chapter Summary

The issue of water protection and conservation is not new. Extensive research and literature has shown the problems that have arisen over time, specifically with regards to agriculture's impact on water quality. The consequences of these problems are not only found within the agricultural industry itself but within society as a whole supporting the need for investment and focus on finding solutions. This chapter has outlined the difficulties in assessing specific problems and refining solutions due to the immense numbers of sources that pollution can come from. The complexity of the dynamics existing within natural environments and their response to agricultural influences still needs to better understood in order to value changes in environmental outcomes.

The implementation of best management practices is an attempt to understand environmental responses to ecological preservation. In this case, water quality and riparian preservation is the issue of focus for BMP analysis. The agricultural industry does have the power to make a difference and become proactive in water conservation techniques and practices. This has been shown with the vast amount of studies evaluating the effectiveness of BMP in an agricultural setting. Not only have findings shown the potential for riparian habitats and water quality, but private benefits to producers have been found. One of these benefits comes in the form of increased livestock gains from cleaner water and pasture distribution from off-stream watering sites. This increase in productivity leads to an increase in a producers' bottom line. With the size of the beef industry within Alberta, the potential for increased returns for producers watering animals from open water sources should lead to adoption. This study will further the literature into the costs/benefits borne/reaped by producers with BMP implementation within Alberta.

Chapter 3 : The Study Area

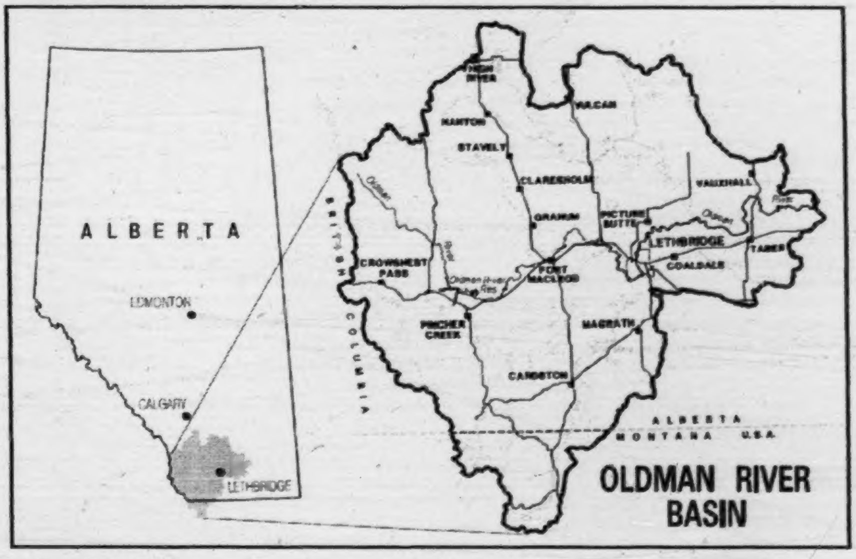
This chapter outlines the agricultural practices and water quality concerns that are found in the Lower Little Bow Watershed region. The intensity of agriculture and its reliance on the availability of abundant fresh water provides this region with the potential for beneficial management practice implementation for water quality. Census data on the types and sizes of farms found in terms of land base and gross receipts provide a representative picture of the intensity of agriculture in southern Alberta. Furthermore, an overview of water quality concerns and the systems that have been put in place to solve water quality concerns support the need for the analysis presented in this study.

3.1 Lower Little Bow Watershed

The Lower Little Bow (LLB) Watershed is located in southwest Alberta in the Oldman River Basin (Figure 3.1). The Oldman River basin covers an area of 28,000 square kilometres. It stretches from High River in the north to Glacier International Peace Park in Montana in the south, as far east as Grassy Lake and west to the Crowsnest Pass in the Rocky Mountains. The largest city in the basin is Lethbridge with approximately 73,000 inhabitants. The entire basin has approximately 161,400 residents.

The site of the study is a micro-watershed north of the City of Lethbridge along the LLB River, in the county of Lethbridge within Census Agricultural Region #2 (Figure 3.2). The site is well suited for agricultural BMP analysis with the wide range and intensities of agricultural activities. Land use includes cow/calf operations, dryland and irrigated farming, and intensive livestock operations. These land use activities provide a good worksite to collect data on the impact of agricultural activities on water quality along the LLB river.

Figure 3.1 - Oldman River Basin and the Lower Little Bow


ALBERTA
EDMONTON
CALGARY
LETHBRIDGE
BRITISH COLUMBIA
HIGH RIVER
VULCAN
NANTON
STAVELY
CLARESHOLM
GRANUM
PICTURE BUTTE
VAUXHALL
LETHBRIDGE
TABER
COALDALE
CROWSNEST PASS
FORT MACLEOD
PINCHER CREEK
MAGRATH
CARDSTON
ALBERTA
MONTANA
U.S.A.
OLDMAN RIVER BASIN

Source: Oldman River Basin (2004)

3.2 Agriculture in the County of Lethbridge

According to 2006 Census of Agriculture data from Statistics Canada, the County of Lethbridge consists of 725,426 acres of farmland comprising 1,058 farms. Of these, 333 farms reported being in the beef cattle ranching and farming industry, including feedlots. Conversely, 464 farms reported being in the grains and oilseed production industry. Table 3.1 shows the distribution of farms size within the county.

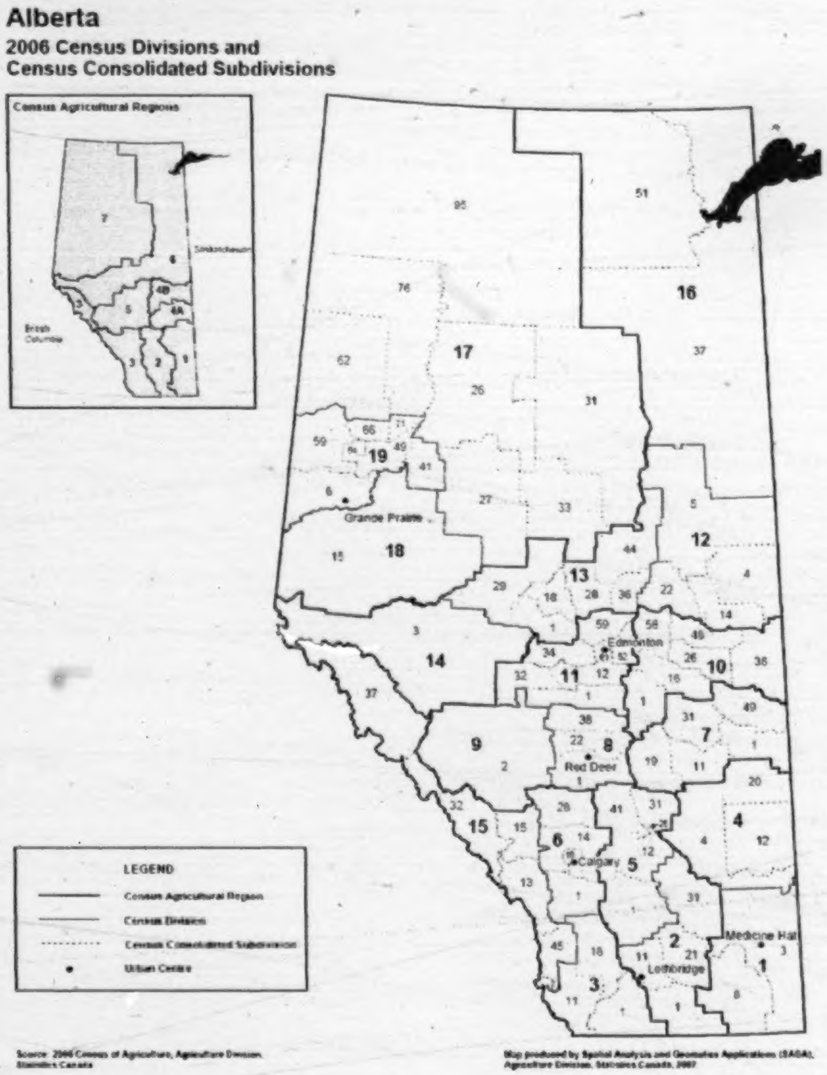
Approximately 70% of farm acres in the county had some form of crop production in 2006. The largest crop seeded, in terms of acreage, was barley with 164,227 acres. This was followed by wheat with 154,512 acres seeded. The total wheat acreage was distributed among spring wheat (70.4%), durum wheat (24.3%) and winter wheat (5.4%). Other crops of significance included oats (4534 acres) and rye (3483 acres). Figure 3.3 shows the historical acreage of major crops seeded in Census Agricultural Division #2 which consists of the counties of Lethbridge (#11), Warner (#1), Taber (#21) and Newell (#31) (Figure 3.2). All wheat is further broken down into durum and spring wheat starting in 1982 in Figure 3.4. Figure 3.5 shows summerfallow as being a large part of crop rotations for the agriculture census area with 347,100 acres being in summerfallow in 2006. In the County of Lethbridge alone in 2006, 45,837 acres were summerfallowed.

Table 3.1 - Distribution of farms by size for the County of Lethbridge

Farm Acreage	Number (Percentage) of Total Farms
Under 130	336 (31.7%)
130-399	328 (31.0%)
400-1,119	230 (21.7%)
1,120-2,239	96 (9.1%)
Over 2,240	68 (6.4%)

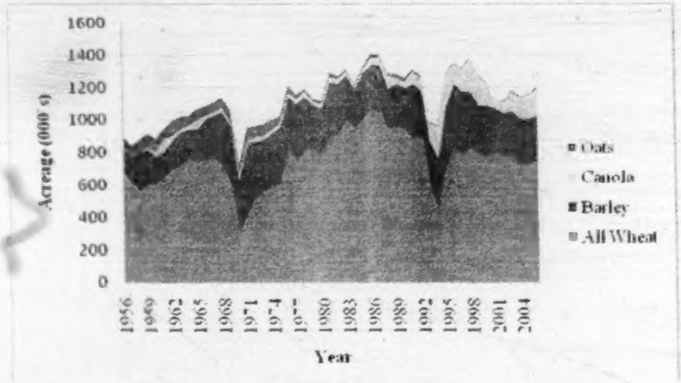
Source: Statistics Canada (2006)

Figure 3.2 - Alberta's agricultural census regions and divisions


Alberta
2006 Census Divisions and
Census Consolidated Subdivisions
Census Agricultural Regions
7
6
5
4B
4A
3
2
1
Saskatchewan
British Columbia
Grande Prairie
Edmonton
Red Deer
Calgary
Medicine Hat
Lethbridge
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
LEGEND
Census Agricultural Region
Census Division
Census Consolidated Subdivision
Urban Centre
Source: 2006 Census of Agriculture, Agriculture Division, Statistics Canada
Map produced by Spatial Analysis and Geomatics Applications (SAGA), Agriculture Division, Statistics Canada, 2007

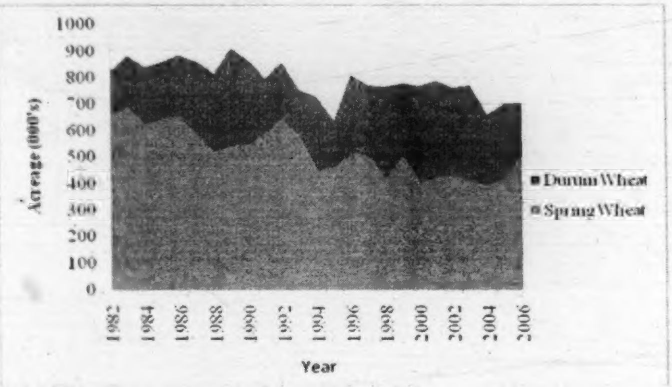
Source: Statistics Canada (2006)

Figure 3.3 - Acreage of major crops seeded in Agricultural Census Division #2



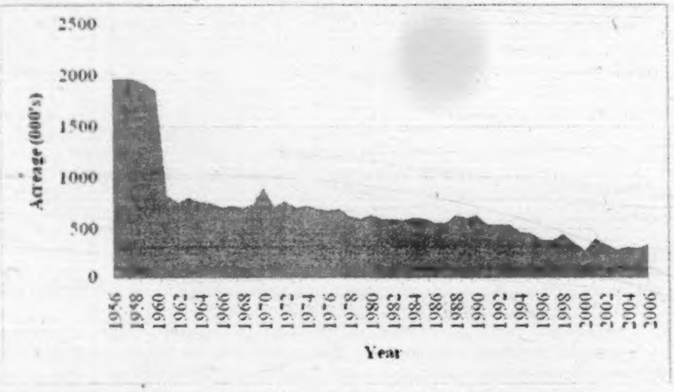
Source: Pearson (2007)

Figure 3.4 - Acreage of durum and spring wheat seeded in Agricultural Census Division #2



Source: Pearson (2007)

Figure 3.5 - Acreage of summerfallow in Agricultural Census Division #2



Source: Pearson (2007)

The large decrease in summerfallow acres in the early 1960's was due to the introduction of more efficient irrigation technology that allowed more acres to come under irrigation which reduces the reliance on summerfallowing to recharge soil water. Prior to the 1960's, the bulk of irrigation was done using gravity processes which involved the flooding of fields through contour ditches. In the 1960's the introduction of level flooding and sprinkler methods allow for easier and more efficient irrigation. This change was supported by the ability to move away from hand-move systems to wheel-move systems (AARD, 2007).

On census day, there were 526,678 head of cattle and calves reported in Lethbridge County. Of that total 103,199 (19.6%) were calves under 1 year, 181,452 (34.4%) were steers and 201,611 (40.0%) were heifers for slaughter. This exemplifies the large cow/calf and finishing capabilities in the county. To support these operations, 76,583 acres were seeded to produce hay (alfalfa, tame, mix) and 136,304 acres were in pastureland (tame, seeded, native).

From census data, all reporting farms in the county are sole proprietorships with 279 of farms being classified as family farms. Gross farm receipts vary widely from less than $10,000 to over $2,000,000. Table 3.2 provides a distribution of gross farm receipts.

This study models and analyzes BMP implementation for an actual farm in the county of Lethbridge. This farm borders the Lower Little Bow River and is an ideal site to study the costs and benefits of BMP implementation from both a biophysical and economic standpoint. Specific details of this farm are described in Chapter 5 and are therefore not discussed here.

Table 3.2 - Distribution of total farm gross receipts for the County of Lethbridge

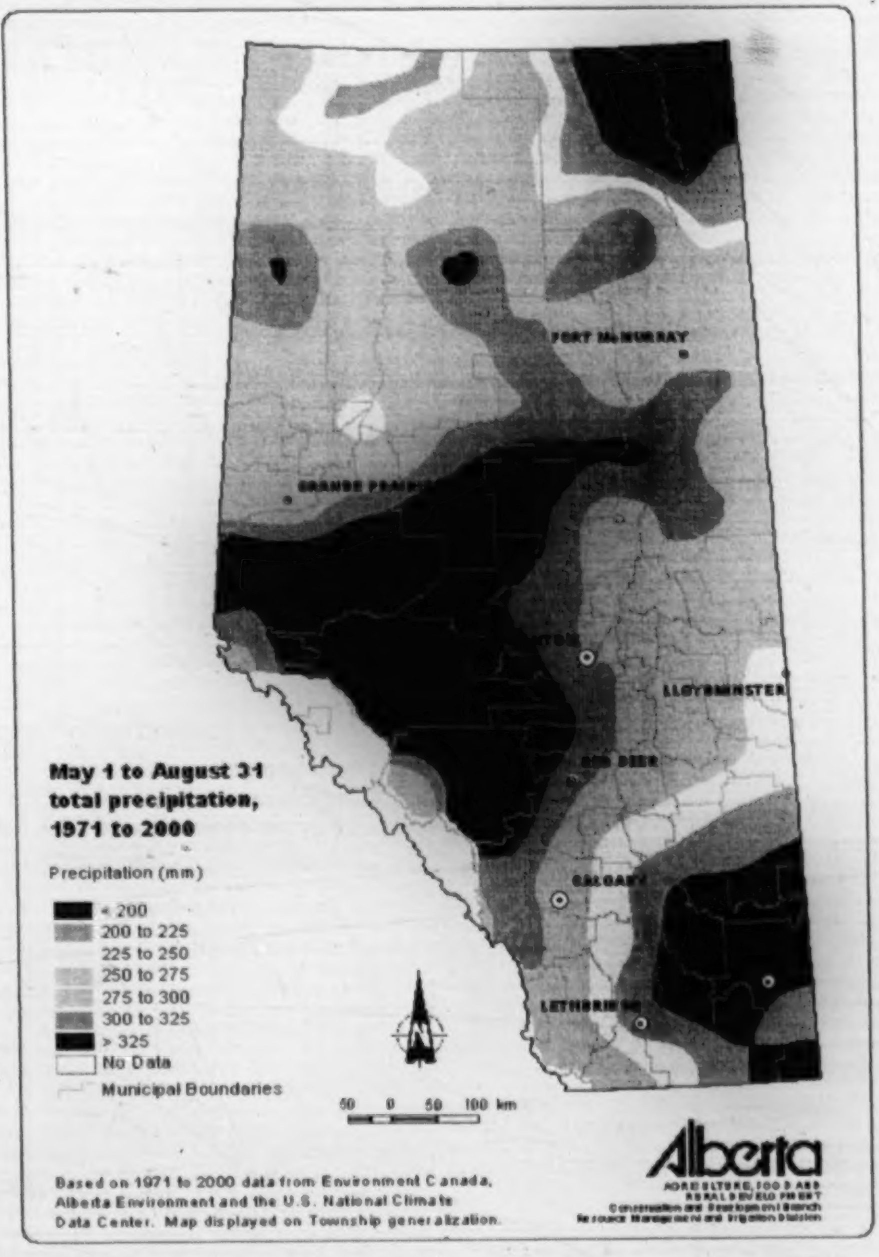
Total Gross Receipts	Number (Percentage) of Total Farms
Under $10,000	127 (12.0%)
$10,000-$49,999	245 (23.2%)
$50,000-$99,999	132 (12.5%)
$100,000-$249,999	178 (16.8%)
$250,000-$499,999	129 (12.2%)
$500,000-$999,999	113 (10.7%)
$1,000,000-$1,999,999	60 (5.7%)
Over $2,000,000	74 (7.0%)

Source: Statistics Canada (2006)

Lying east of the Rocky Mountains, the area receives relatively less moisure but more heat compared to the rest of the province. Figure 3.6 shows the historical precipitation between May 1 and August 31 and according to Alberta Agriculture and Rural Development. Figure 3.7 shows the heat that southern Alberta recieves in terms of growing degree days. Growing degree days is an estimate used to assess the potential growth and development of plants during a growing season. A more in-depth discussion of growing degree days occur Chapter 5. Basically, however, plant development will only occur if air temperature exceeds a base temperature.

The culmination of these two factors explains the large wheat and barley acreages. Barley is a very genetically diverse crop that can be grown in many different climatic conditions including southern Alberta, as the prepitation received in southern Alberta is satisfactory for barley production (AARD, 2006-a). This is also the case for wheat; wheat is able to handle areas and growing seasons with relatively low moisture and high heat. Producers do utilize irrigation in areas where moisture is not sufficient to produce consistent crop yields over time. Consequently, 6% of Alberta's agricultural land base utilizes irrigation to provide moisture to soils and growing crops and most of this irrigated land is found in the study area (AARD, 2008).

Figure 3.6 - Precipitation in Alberta



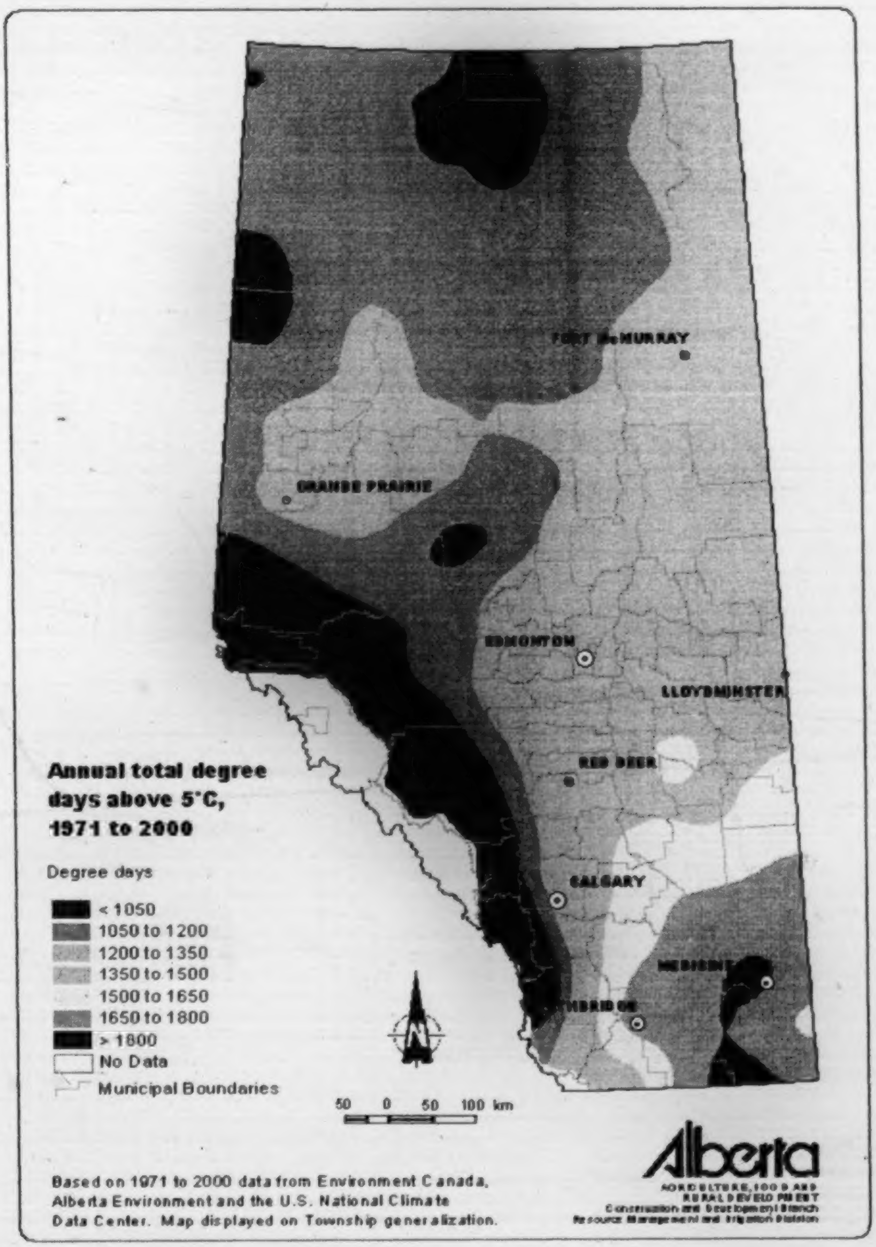
May 1 to August 31 total precipitation, 1971 to 2000

FORT McMURRAY
GRANDE PRAIR
TON
LLOYDMINSTER
RED DEER
CALGARY
LETHBRIDGE
Precipitation (mm)
< 200
200 to 225
225 to 250
250 to 275
275 to 300
300 to 325
> 325
No Data
Municipal Boundaries
50 0 50 100 km
Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT
Conservation and Development Branch
Resource Management and Irrigation Division

Based on 1971 to 2000 data from Environment Canada, Alberta Environment and the U.S. National Climate Data Center. Map displayed on Township generalization.

Source: AARD (2008-f)

Figure 3.7 - Growing Degree Days in Alberta

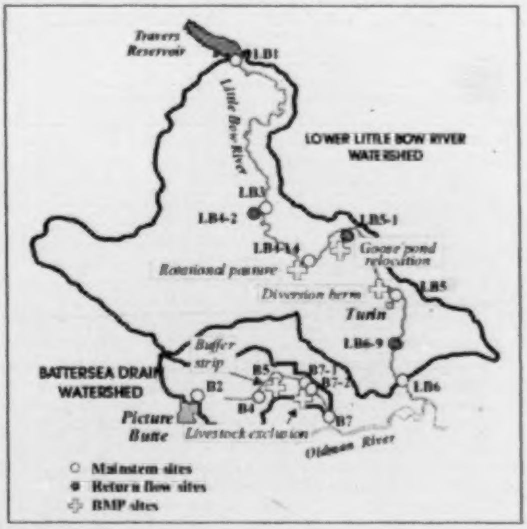

FORT McMURRAY
GRANDE PRAIRIE
EDMONTON
LLOYDMINSTER
RED DEER
CALGARY
MEDICINE HAT
LETHBRIDGE
Annual total degree days above 5°C, 1971 to 2000
Degree days
< 1050
1050 to 1200
1200 to 1350
1350 to 1500
1500 to 1650
1650 to 1800
> 1800
No Data
Municipal Boundaries
N
50 0 50 100 km
Based on 1971 to 2000 data from Environment Canada, Alberta Environment and the U.S. National Climate Data Center. Map displayed on Township generalization.
Alberta

Source: AARD (2008-g)

3.3 Water Quality Initiatives

The Oldman Watershed Council, in partnership with Alberta Agriculture, Food and Rural Development, has been monitoring water quality in the Lower Little Bow Micro Watershed and Battersea Drain since 1999. Water quality was monitored in an effort to evaluate the effectiveness of best management practices. The water quality in the Lower Little Bow and Battersea Drain was measured using three criteria: nutrients, bacteria and flow. There were eight study sites along the river (Figure 3.8). Water samples and flow data were taken year round at upstream and downstream sites.

Figure 3.8 - Oldman Watershed Council study sites in the County of Lethbridge


Travers Reservoir
LB1
Little Bow River
LOWER LITTLE BOW RIVER WATERSHED
LB3
LB4-2
LB5-1
LB4-A
Goose pond relocation
Rotational pasture
Diversion berm
LB5
Turin
LB6-9
Buffer strip
BATTERSEA DRAIN WATERSHED
B5
B7-1
B7-2
B2
LB6
B4
Picture Butte
B7
Livestock exclusion
Oldman River
○ Mainstem sites
● Return flow sites
BMP sites

Source: AARD (2003)

Nutrients tested included nitrogen and phosphorus. High levels of nitrogen and phosphorus can lead to eutrophication which may lead to excessive plant growth and decay. This, in turn, can result in oxygen depletion and a reduction in water quality. Increased nitrogen levels may have human and livestock health implications if the nitrogen is ingested and nitrogen in the form of ammonia can be toxic to fish. Results of 4 years of testing (1999 – 2002) showed an increase in both nitrogen and phosphorus levels during times of high rainfall (AARD, 2003). The higher precipitation caused increased surface runoff from farmland, thus reducing water quality. Years with drought conditions showed a decrease in nitrogen and phosphorus levels due to less surface runoff.

Bacteria in the form of fecal coliforms and E.Coli were measured to indicate levels of fecal contamination in the water. At upstream sites, 90% of samples met recreational fecal coliform guidelines, whereas 17% and 41% of samples met Alberta Environment guidelines in 1999 and 2001 respectively (AARD, 2003). These guidelines are set to guide in the evaluation of surface water quality in Alberta. Alberta Environment states that these guidelines, along with site monitoring data, can be used to identify possible water quality concerns. Flow volume has a large impact on the load of a river which leads to an evaluation of the impact on receiving water bodies such as the Oldman River. Larger flows were seen in times of high precipitation which was also a time of increased nitrogen, phosphorus and fecal coliform levels. Analysis showed that flow levels, due to higher precipitation levels, were the leading cause of upstream runoff. This runoff impacted water quality downstream, where the Lower Little Bow flowed into the Oldman River. Table 3.3 summarizes the results from the Lower Little Bow test sites between the years 1999 and 2002. The water quality index values were derived by measuring the number of test samples that exceeded guidelines and by how much/often they exceeded guidelines, "excellent" being good test results and "extremely poor" being the worst.

Table 3.3 - Water quality index ratings for the Lower Little Bow drain sampling sites[2]

	Water Quality Index Category			
Site	**1999**	**2000**	**2001**	**2002**
LB1	Excellent	Excellent	Excellent	Good
LB2	Fair	Good	Good	Fair
LB3	Fair	Good	Good	Fair
LB4-2	Extremely Poor	Extremely Poor	Extremely Poor	Poor
S1	Poor	Good	Extremely Poor	Poor
LB4-14	----	Good	Fair	Extremely Poor
LB4	Extremely Poor	Fair	Fair	Extremely Poor
LB5-1	Poor	Poor	Fair	Poor
LB5-10	----	Good	Fair	Extremely Poor
LB5	Extremely Poor	Good	Fair	Poor
LB6-9	----	Fair	Fair	Poor
LB6	Extremely Poor	Fair	Fair	Poor

Source: AARD (2003)

The research concluded that the quality of water flowing downstream towards the Oldman River worsened. The Oldman River flows to the South Saskatchewan which is the water source for Medicine Hat in southeastern Alberta. Even though the flow of the Lower Little Bow River is minute compared to the Oldman river (3% of flow), the culmination of all rivers and streams feeding into the Oldman River may have a large impact on water quality (AARD, 2003). These other rivers include the Crownest River, Livingstone River, Castle River, Beaver Creek, Pincher Creek, Willow Creek, Belly River and the St. Mary River. The Crowsnest River originates from the Crownest pass in the Rocky Mountains and boasts world-class sport fishing sites. The St. Mary River is a substantial river located in Canada's largest irrigation district (St. Mary River Irrigation District) and provides irrigation for 1,505 square kilometres of land between Lethbridge and Medicine Hat. The importance of water in southern Alberta in terms of its private and social benefits has led to the implementation of BMP test sites within the Lower Little

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[2] Water quality ratings from best to worst are: Excellent, Good, Fair, Poor, Extremely Poor. In the original reference, "Borderline" is used in place of "Extremely Poor" in this table.

Bow Watershed. These sites incorporated practices such as livestock relocation through off-stream watering, buffer strips, rotational grazing, cattle access ramps, riparian fencing and others. (AARD, 2003)

In the Battersea Drain, 30 metre buffer strips (Figure 3.11) and livestock exclusion with off-stream watering sites (Figure 3.12) were implemented. Final results showed once again that river flow was the major determining factor in nutrient and bacteria levels downstream. The buffer strips absorption capacity was not able to support the amount of nutrients moving from cropland to water. No conclusive evidence was found that supported livestock fencing as an effective means reducing nutrient and bacteria levels. This may have been due to the fact that upstream and downstream data were not available to confirm the initial impact of cattle on water quality. (AARD, 2003)

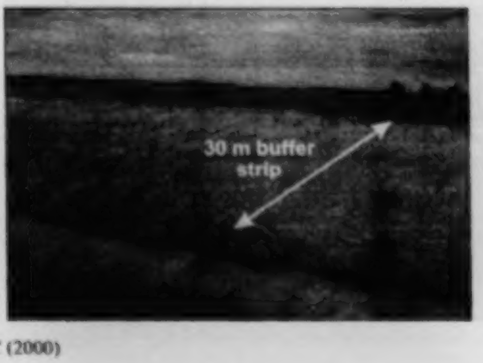
Results differed at the Lower Little Bow sites. At one site, 800 metres of fencing was constructed on both sides of the river and a small river crossing was available for cattle to cross (Figure 3.13). Off-stream watering was available for the animals in the three pastures through which the animals were rotated. There was a dramatic decrease in the bacteria levels found in the spring that was attributable to this BMP, but higher flow still seemed to bring higher nutrient levels. Overall, a longer period of time is needed to determine the real benefits of BMP implementation (AARD, 2003), but it has been shown that there are some immediate impacts of implementing best management practices.

3.4 Chapter Summary

The Lower Little Bow watershed is located in the agriculturally intensive Oldman River Basin in southwestern Alberta. The land and climatic conditions are well suited for agricultural production and there is a wide variety of farm types that occupy a large land base. One third of the farms are directly involved in the cattle industry and nearly half of all farms are directly involved in the grains and oilseeds production industry. The distribution of gross farm receipts shows the wide range of farm sized and production intensities.

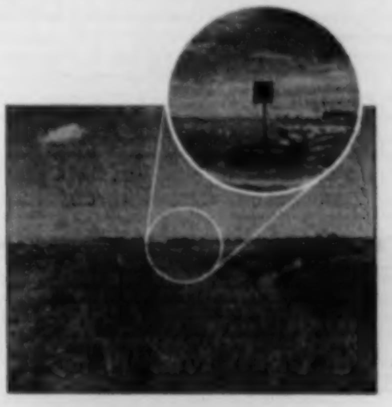
It is not a secret that there is a heavy reliance on having a source of fresh water for livestock and crop production. The Lower Little Bow watershed is located in an area that does utilize some irrigation and water conservation practices. Consequently, there has been an ever increasing understanding that water preservation and conservation programs are needed to assure that water remains available for agricultural activities. More importantly, the water quality programs need to assure public citizens that drinking water is safe and reliable and that a steady supply will continue to be available in the future.

Figure 3.9 - Buffer strip along the Battersea Drain



Source: AAFC (2000)

Figure 3.10 - Livestock exclusion with off-stream watering along the Battersea Drain



Source: AAFC (2000)

Figure 3.11 - Rotational pasture along the Lower Little Bow River

Source: AAFC (2000)

Chapter 4 : Capital Budgeting and Simulation Analysis

This study incorporates the use of Monte Carlo simulation in conjunction with capital budgeting techniques to study the costs and benefits of BMP implementation. This chapter outlines various capital budgeting techniques and a theoretical discussion provides the benefits of using net present value as the capital budgeting approach in this study. The benefits and strengths to using simulation in this study are outlined, followed by the specific model structure of the farm in the Lower Little Bow.

4.1 Capital Budgeting

Capital budgeting is a planning tool used to analyze and evaluate long term investments for a firm. The capital budgeting technique that is used most frequently is some form of discounted cash flow including net present value (NPV) and the internal rate of return (IRR) (Ross et al, 2003). There are other capital budgeting techniques that are used in the investment decision process including the payback period (PBK) and the average accounting return (AAR). Table 4.1 shows a summary of a survey performed on large firms asking what type of investment criteria was used in an investment decision. It is clear that there is no single technique that is preferred by all firms who are researching investment possibilities.

Table 4.1 - Propensity to use various capital budgeting techniques

Model Used	Replacement Project (%)	Expansion – Existing Operations (%)	Expansion – New Operations (%)	Foreign Operations (%)
Average Accounting Return	14.9	17.5	19.9	14.6
Internal Rate of Return	51.2	64.3	65.1	67.0
Net Present Value	38.0	42.9	47.6	47.6
Payback Period	53.7	52.4	50.0	50.0

Source: Ross et al. (2003)

Long term investments are typically characterized by requiring an initial capital outlay (i.e., initial investment). This capital investment then generates a stream of cash flows, both positive and negative, over time. Any method used to evaluate long term investments should incorporate the magnitude and timing of cash flows as well as the time preferences of the decision maker(s). Finally, the information provided by the evaluation method should indicate the potential profitability of the investment relative to the opportunity cost of capital for the decision maker(s).

Of the four capital budgeting methods identified above, internal rate of return (IRR) and net present value (NPV) are considered for use in this study. These two alternatives are discussed and compared below. The average accounting return and payback period will not be used or discussed further. These two are not realistic measures to use for a detailed economic study of investment decisions similar to the cost/benefit analysis undertaken in this study because of limitations with respect to the desired characteristics for a capital budgeting method (Ross et al., 2003).

4.1.1 Capital Budgeting Techniques

4.1.1.1 Net Present Value (NPV)

In its most basic form, NPV is defined as the present value of future net cash flows minus the costs of investment (Ross et al, 2003). The concept of present value is one of the most important concepts in farm and corporate finance. Present value takes into account the time value of money and puts a value on a future payment or a series of future payments in terms of its worth at the present time. Present value (PV) is calculated as the value of a future cash stream discounted at an appropriate market rate and is shown by the following formula (Ross et al., 2003):

$$PV = \frac{C_1}{1+r}, \tag{4.1}$$

where C_1 is the cash flow at date 1 and r is the interest rate, otherwise known as the discount rate. This discount rate is often chosen to be representative of the market interest rate or the rate that is paid on bank deposits or other financial investments. Other approaches to calculating a discount rate may be used that are based on the firm's cost of capital. These are discussed later in this chapter.

A hypothetical example may be used to illustrate the present value concept and calculation. If the discount rate is equal to 10%, a $1,100 payment received one year from now has present value of $1000; that is, PV = 1100/(1.10). This is equivalent to the statement that if $1,000 is invested at a 10% interest rate today, it would have a value of $1,100 in one year. The principle behind this calculation is referred to as the time value of money. This process and concept of present value provides a means to compare cash flows occurring at different times by putting them on a consistent time basis. PV tools are used widely in business and economics to analyze investment decisions.

Net present value accounts for any capital outlays that are needed before future cash flows or a change in future cash flows can come about. Thus:

$$NPV = \frac{C_1}{1+r} - I_0, \qquad (4.2)$$

where I_0 is the initial cash outlay of the investment (Ross et al., 2003). The present value of the future cash flow is compared to the initial capital outlay. If the net difference is non-negative, then the investment is earning at least the required rate of return as represented by the discount rate.

Most investment projects have a lifespan and resulting net cash stream of more than one time period. In this case, NPV is calculated using equation 4.3 or 4.4, which represent the general NPV formula for an investment that generates cash flows over N time periods:

$$NPV = \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \frac{C_3}{(1+r)^3} + \ldots \frac{C_n}{(1+r)^n} - I_0, \qquad (4.3)$$

$$NPV = \sum_{t=1}^{N} \frac{C_t}{(1+r)^t} - I_0 . \qquad (4.4)$$

If an investment's NPV is negative, the present value of cash outflows and/or the initial investment exceed the present value of cash inflows and the investment should not be undertaken as it is not sufficiently profitable. In other words, the return earned is not at least equal to the opportunity cost used in discounting the future cash flows. The opposite is true if the NPV is non-negative.

4.1.1.2 Internal Rate of Return (IRR)

The internal rate of return is very similar to NPV. It also involves discounting future cash flows similar to the NPV calculation. The difference is that the opportunity cost of capital is not used as the discount rate. Instead, the IRR is calculated to be the discount rate, r, or rate of return, that results in an NPV of zero for the investment. The implication is very simple; the firm would accept or reject an investment project if the discount rate is lower or higher than the IRR, respectively. From Ross et al. (2003), the formula is:

$$NPV = 0 = \sum_{t=1}^{N} \frac{C_t}{(1+IRR)^t} - I_0, \qquad (4.5)$$

A major strength of this approach is that it is relatively straightforward for managers to interpret the IRR. As a percentage, it can be directly compared to market rates. Also, similar to the NPV, the IRR incorporates all cash flows. However, a limitation of the IRR is the assumption with respect to reinvestment. It is assumed with the IRR that the investor can invest any money earned from the investment into a money market instrument at the same rate as the IRR which is not always the case, particularly if the IRR is sufficiently large (Copeland et al., 2005).

4.1.2 The Use of NPV

A comparison of the pros and cons for each of the capital budgeting techniques as well as an examination of previous research investigating similar economic problems support the use of net present value analysis in the study. NPV was chosen over IRR as it is easier to apply than IRR (Ross et al, 2003). As noted earlier, a flaw for the IRR is the assumption of reinvestment at a rate equal to the IRR; that is, it uses the same discount rate for everything. Also, caution should be taken in using IRR analysis if future cash flows are sufficiently variable that they change “sign” (i.e., positive to negative, or vice versa) multiple times. In those situations, a project will have multiple IRR’s as multiple rates of return will be capable of making equation 4.5 equal to zero (Ross et al, 2003).

In this study, cash flows are subject to significant variability due to changing market conditions for beef and crop prices. There is also significant variation in crop yields due to weather variability. As a result, using IRR may prove problematic for the comparison of BMPs. For this study, the final NPV of the farms cash flows are what will be compared. It is easier and more relevant to compare the differences in net present values of BMP implementation and the reference farm than the discount rates that set NPV to zero. The difference in net present values will indicate if BMP implementation is beneficial or costly to the agricultural producer.

Previous studies that have undertaken research in agricultural investment decisions similar to this one have used a similar approach and are briefly outlined here. Cortus (2005) used simulation analysis and NPVs to examine the feasibility of wetland drainage for increased crop production. Drainage was viewed as an investment decision as capital investments were needed to accomplish drainage in the form of machinery purchases which impacted cash flows over time. Similarly, in this study investment in materials must be undertaken to implement at least some of the BMPs under consideration. In Cortus' study, distributions for NPV resulting from Monte Carlo simulation were compared, and it was concluded that drainage practices were economically feasible under certain conditions in the geographical area considered in the study.

Miller (2002) also used simulation and NPV analysis to evaluate on-farm costs and benefits of various riparian management schemes on a hypothetical southern Alberta ranch. Miller compared the overall feasibility and impact of various grazing strategies. These strategies included over-grazing and conservative grazing of pastures from different pasture starting conditions. Using this scenario analysis and Monte Carlo simulation, NPVs were calculated using the trend in cash flows over 20 grazing periods for each scenario. From the results it was concluded that on a healthy pasture, a conservative grazing strategy would give the most favourable financial outcome. By conservatively grazing, rather than over-grazing pasture, the productivity is sustained from year to year allowing for a reliable source of grazing forage overtime. On a range in poor condition, overgrazing the site is the most financially attractive option.

4.1.3 Determining a Discount Rate for Net Present Value Analysis

As discussed earlier, the discount rate is used to discount future cash flows to their present values in the calculation of net present value. The discount rate is also known as the required rate of return and should be represent the rate of return for the best alternative opportunity for using that capital (Ross et al., 2003). The choice of discount rate is of crucial importance as it is often a key element in determining whether a NPV is positive or negative. A NPV calculation over an extended time period with large cash flows is very sensitive to the magnitude of the discount rate and this argument can be tested using equations 4.3 or 4.4.

In the literature, alternative approaches are used to specify a representative discount rate to be used in calculating NPVs for capital investments or projects. A simple approach to choosing a discount rate for a project is to determine the rate of return of alternative projects that are available. For example, if the rate of return for another project is eight percent, then eight percent could be used.

Another approach is to use a firm's weighted average cost of capital (WACC) as the discount rate. The WACC is a weighted average of a firm's cost of debt and cost of equity where the weights are the proportions of debt and equity capital making up the firm's capital structure. Ross et al. (2003) defines the discount rate resulting from the use of WACC as:

$$r_{wacc} = \frac{S}{S+B} * r_s + \frac{B}{S+B} * r_B * (1 - T_C), \qquad (4.6)$$

where S is the firm's total market value of equity, B is the firm's total debt, r_s is the required/expected rate of return of equity (cost of equity), r_B is the required/expected rate of return of debt (cost of debt) and T_c is the corporate tax rate. It has been hypothesized that using WACC as the discount rate may underestimate the riskiness of new projects; that is, the resulting discount rate may underestimate the true required rate of return for risky investments. This is because of the corporate tax rate, T_c, which may be overestimated over the life of the investment period. Since a firm should only proceed with a project if the expected rate of return sufficiently compensates for the risk undertaken (Ross et al., 2003), this is a significant potential issue.

Furthermore, using the WACC method requires an understanding of the capital structure of the farm in terms of the amount of debt and equity present in the operation, in order to provide a discount rate. In other words, the discount rate is dependent on the leverage position of the farm. Information about capital structure is not available for the representative farm. If it were however, the WACC method may still prove to be unreasonable to use as capital structure is always subject to change resulting from such decisions as equipment or land purchase and/or sale.

Capital Market Line (CML) theory can also be used to derive a discount rate that accounts for the riskiness of alternative investments. The concept of the CML is based on levels of risk and return for projects, and is illustrated in Figure 4.1. The feasible set of risky portfolios, otherwise known as the efficient frontier, in Figure 4.1 represents all possible combinations of riskless and risky assets that are feasible subject to a budget constraint. The CML is derived by drawing a tangent line from the point on the efficient frontier to the point where the expected return equals the risk-free rate of return. The optimal market portfolio lies at point B, which is the point of tangency with the efficient frontier (Ross et al., 2003). The CML represents risk and return generated by portfolios that combine the optimal market portfolio and the risk free asset. At point A, the portfolio has a larger proportion of risk-free asset as compared to point C; a higher weighting in the risk-free asset reduces the standard deviation of the portfolio and thus the expected return. As the risk free rate increases, the optimal portfolio moves towards C, the opposite occurs as the risk-free rate decreases.

All combinations on the CML are efficient and are superior to the feasible set of risky portfolios that make up the efficient frontier. The choice of portfolio on the CML will depend on risk preferences for the investor. A risk averse investor may choose a standard deviation at point A and a risk seeking investor may be comfortable with a risk level at point C.

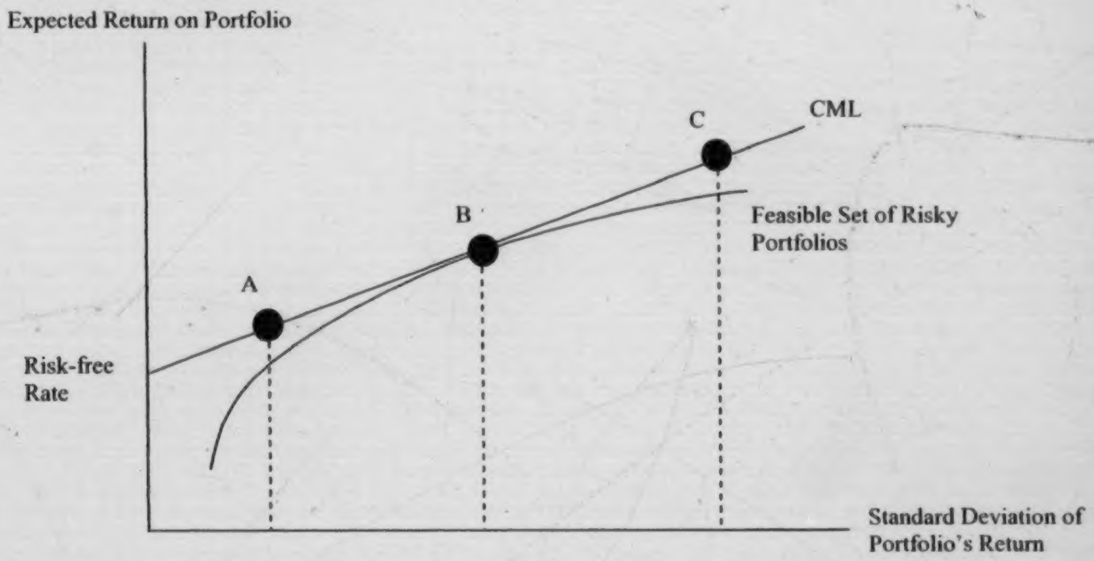
The CML concept is used in this study to determine the appropriate discount rate for NPV analysis. However, instead of using the CML to determine the optimal asset mix to meet a desired risk level for the investor as explained above, the opposite is true. In this case, the portfolio of assets to be considered is the representative farm and all of its relationships and characteristics. CML theory is used to ascertain the appropriate discount rate to represent the risk or expected return of farming activities. The formula to calculate the expected return for the farm is shown below from Sharpe et al. (2000):

$$\overline{r_p} = r_f + \left[\frac{\overline{r_m} - r_f}{\sigma_m} \right] \sigma_p, \qquad (4.7)$$

where $\overline{r_p}$ is the farm's expected return or the discount rate of the farm, r_f is the market risk free rate, $\overline{r_m}$ is the expected market return, σ_m is the standard deviation of the market portfolio and σ_p is the standard deviation of the farm's returns; $\left[\frac{\overline{r_m} - r_f}{\sigma_m}\right]$ is essentially the slope of the CML.

To calculate $\overline{r_p}$, the variables r_f, $\overline{r_m}$ and σ_m must be determined. The rate of return for government treasury bills can be used as the risk-free rate. Treasury bills are considered to be risk free money market instruments as they are financially guaranteed by governments. A stock market index such as the S&P/TSX Composite Index can be used to estimate market returns and standard deviation. What is more difficult to find is the standard deviation of farm returns, σ_p. Unless all historical data is available for all aspects of the farms cash flows and the events that impacted the cash flows such as weather etc., which is unlikely, estimating the exact standard deviation is impossible. Copeland and Antikarov (2003) outline a simple solution to this problem which incorporates Monte Carlo simulation. This is explained in the following section.

Figure 4.1 - The Capital Market Line



4.1.3.1 Determining the Volatility of an Assets Returns

No two firms (or farms in this case) are exactly the same. The management styles, strategies, physical characteristics and economic relationships will differ from one farm to the next. Therefore it is difficult to generalize a standard deviation or volatility of a farm's financial returns. Copeland and Antikarov (2003) outline a solution that allows simulation analysis to be used to estimate the volatility of farm returns; that is, to solve for σ_p in equation 4.8. Assuming that all economic and biophysical relationships are known and modelled correctly and all input information is available, Monte Carlo simulation can be used to estimate the volatility of the rate of return for the farm. The following relationship is used which is similarly outlined by Copeland and Antikarov (2003);

$$\overline{r_p} = \frac{NPV_1 - NPV_0}{NPV_0}, \qquad (4.8)$$

where $\overline{r_p}$ is the farm's expected return, NPV_1 is the net present value from time period 1 to 'n', and NPV_0 is the net present value from time period 0 through 'n'. Initially, an arbitrary discount rate must be chosen for the NPV analysis. Previous literature and studies have used an initial discount rate of 10% for agricultural production firms. Through the use of Monte Carlo simulation methods, described later in this chapter, iteratively running the simulation model results in a probability distribution for $\overline{r_p}$. This distribution is then used to calculate σ_p. This estimate of σ_p is then substituted back into equation 4.8 to generate the appropriate discount rate for the farm being studied.

4.2 Agricultural Systems Modelling

Agricultural producers operate in a dynamic and complex environment where physical and economic variables are frequently undergoing change (Dent et al., 1986). In an effort to best represent this complexity, a decision needed to be made as to the best approach to use in order to model the economics of best management practice implementation. Two alternative modeling approaches are mathematical programming and simulation. Each of these are discussed, in turn, in terms of pros and cons.

4.2.1 Mathematical Programming and Optimization

Mathematical programming models are tools that may be used to determine the best way to achieve an optimal outcome subject to a set of requirements or constraints. In a mathematical sense, optimization attempts to achieve an efficient solution by maximizing or minimizing a mathematical function subject to constraints. In the context of a production economics problem, the objective may be to maximize profit or minimize cost subject to a set of constraints that represent technology and availability of limited resources. A farm is no different from any other business in the sense the management problem is to allocate a limited amount of physical, financial and human resources to achieve a set of desired outcome.

An example of an agricultural application is finding the optimal (i.e., least cost) ration for cows subject to the type of individual feeds available and requirements for total feed and energy. The producer has the option to choose from a variety of feed types to formulate this mix and each feed type has a different cost. The producer must provide at least a minimum required amount of feed in kilograms as well as a minimum required amount of energy to each animal in the herd. Feedstuffs with high energy contents are more expensive and using only this feed type will not meet the minimum feed requirement. The cheapest feed will meet the kilogram requirement for feed but it will not meet the energy needs. Mathematical programming can be used to determine the optimal mix of feed that will meet the kilogram and energy requirements at the least cost.

Mathematical programming models represent one of the most widely used operations research methods for agricultural planning (Dent et al., 1986). The main advantage to this method is that it permits the assessment of a wide range of alternative actions or choices with a small input of time (Beneke and Winterboer, 1973). For example, a model that is developed to solve the above ration example can be easily adjusted to examine changes in the optimal feed mix if a feed price increased by 10% or the energy needs of the herd dropped by 5%. Furthermore, by using models developed to make the best possible use (i.e., optimal use) of available, there is less wastage of time and money attributable to trial and error attempts to find the optimal solution.

There are also some significant limitations to mathematical programming and optimization in its role as a farm planning tool. These limitations arise primarily because of the somewhat rigid structure of these models and the difficulty in incorporating complex relationships. Mathematical programming models are structured as a constrained optimization problem where there is a single objective and a set of constraints. Multiple objectives are difficult to incorporate (although this can be done through tools such as goal programming), and all relevant relationships must be specified in the form of constraints.

More significant, from the perspective of the current study, is the restrictiveness of mathematical programming models with respect to incorporating complex relationships. For example, while risk can be incorporated into mathematical programming models, typically the way in which it is modeled is limited by the required structure of this methodology. It is difficult to incorporate flexible specifications of probability distribution functions, for example. The structure of these models also makes it difficult to incorporate such relationships as price expectations, if these take on a time series form.

4.2.2 Simulation Analysis

Simulation modelling is the process of constructing a model that encompasses relevant variables and relationships that characterize a real system. This model is then run repetitively generating a stream of behaviour that, when represented correctly, would be expected from a real system under similar conditions (Babb et al, 1963). A system is defined as a collection of entities that interact toward the accomplishment of some logical end (Law and Kelton, 2000). A simulation system can be static, which is a representation of a system at a particular time, or it can be dynamic in that the model representation evolves over time. Furthermore, deterministic models contain no random variables compared to stochastic simulation models that do include random variables. The decision to use either one of these models of a combination of each depends on the objectives of the study (Law and Kelton, 2000).

Where mathematical programming provides an analytic solution based on the exact information on the question of interest, simulation accounts for the fact that most real world systems are too complicated to be evaluated analytically. Furthermore, unlike mathematical programming, simulation allows for the study and understanding of the underlying relationships of a system and helps to predict the response to new operating policy (Law and Kelton, 2000). Hence, in simulation, a model is evaluated over a time period of interest to estimate the desired true characteristics of the model using internal relationships and external factors representing reality.

Historically, simulation analysis has been a dominant tool within the field of operations research (Nance and Sargent, 2002) and it continues to be useful to this day. The goal of simulation analysis can be generalized into two categories (Peart et al, 1997). The first is the representation of systems analysis, whereby the goal is to understand or improve systems performance. The second is education and training, whereby education deals with gaining a broader understanding of concepts and training pertains to the specific applications of concepts. An example of the first type of application would be the current study, in which the production and financial "systems" for a farm operation are studied in order to examine the impact on performance of a change in those systems. An example of the latter type of application would be flight simulation programs whereby prospective pilots learn general and specific skills of flying an airplane.

Agricultural simulation models are a key tool in systems analysis research, policy formulation and teaching (Bechini et al., 2007). Simulation models have been developed to further our understanding of many agricultural processes from crop rotation and environmental interactions to beef performance based upon feeding regimes fulfilling the first category described above. The following provides some examples of simulation models developed to understand and investigate agricultural systems.

Models of complex cropping systems have been developed to evaluate the impact of agriculture on economic, environmental and human health related issues (Donatelli, 2002). Dynamic models in agroecology, the study of applying ecological concepts and principles into the design of sustainable agricultural systems, have given a deeper understanding of the relationship between soils, plants and the atmosphere in growing environments (Poluektov et al., 2001). Bioeconomic models predict management responses to biological processes, usually in terms of economic performance, and have been used extensively in agricultural systems modelling (King et al., 1993). Mapp and Eidman (1976) produced a bioeconomic simulation model to stochastically determine yields for dryland and irrigated crops and the impact on a producers' financial health.

Boggess et al. (1985) developed a bioeconomic decision making simulation tool to aid managers in the implementation of multi-species insect management strategies.

Beef simulation systems represent another large branch of applications within agricultural simulation. Pang et al. (1999) simulated a beef cattle production system to evaluate the effects of production traits and management strategies on the bioeconomic efficiency of beef systems. This simulation system was composed of a herd inventory model, nutrient requirement model, forage production and economic models. All of these were linked together to provide an overall bioeconomic model of the system. Gradiz et al (2007) developed a simulation model between a beef cow/calf production system and a sugarcane production system to replicate energy and protein requirements for cows and calves.

Ipe at al. (2001) used simulation analysis to examine issues similar to the current study. Simulation was used to understand how a group incentive program for producers would foster implementation of best management practices for a watershed in Central Illinois. The simulated variables were incentive payments, program costs and environmental impacts of the program. The incentive program was offered to producers who participated and implemented BMPs. These producers were guaranteed the same level of profit as producers who did not participate in the project. In other words, the compensation scheme reimbursed participating producers for lost income. The long-run average and current average incomes for the two groups were calculated as a comparator. Participating producers were compensated when the percentage deviation in the long run average was larger than the percentage deviation for non-participating producers. The BMPs at issue were changing the timing of fertilizer application and reducing the application rate.

The simulation was run under a wide range of fertilizer application rates. Iterations generated the returns per acre and environmental outcomes which were compared to a baseline case that was representative of the actual producers in Central Illinois. Results showed that participating producers actually had a higher level of expected profits when fertilizer rates were reduced. These results clarified that producers may be applying more than the profit-maximizing level of fertilizer. Environmental impacts were measured in terms of nitrate emissions per acre and nitrate concentration in the lake within the watershed. The base timing schedule for fertilizer application was 75% fall application and 25% spring application. The simulation showed that as fertilizer rates decreased, nitrate emissions decreased. Furthermore, a simple change of application timing to 50% fall application and 50% spring application reduced nitrate emissions even while using the same amount of fertilizer as in the base case. A change in the fertilizer timing and rate also resulted in an improvement of water quality in the lake.

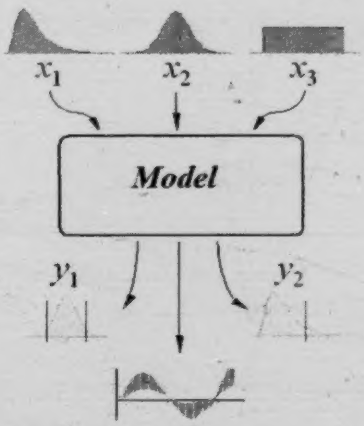
However, even with the large amount of literature available on cropping or beef simulations, there seems to be a lack of research performed at a large scale level where farm includes both cropping and livestock enterprises and the relationships that occur between the two enterprises. The following sections describe the "mixed" farm simulation that has been developed in this research project.

A key advantage of simulation analysis over optimization is the ability to integrate flexibility and uncertainty (Evans and Olson, 2002). Implementing BMPs within a computer simulation model is relatively fast and inexpensive. However, there is a risk that results may be less credible as it is difficult to model all cause and effect relationships (Rotz and Veith, 2006). This is the drawback of any simulation model; that is, the ability to model all relationships is limited by the uncertainty of interaction when implementation is done in reality (Law & Kelton, 2000). With regards to this study, BMP implementation is rather straightforward within the simulation model but the results will not provide a "concrete" answer to the research question. Since simulation can work over space and time, allowing one to perceive any interaction between variables rather easily, it is the closest thing to understanding the real-life costs/benefits of BMP implementation. That makes this the proper modelling choice over mathematical programming and optimization. It allows for the avoidance of large financial commitments, (i.e., no need to pay the investment of actual implementation), time commitments, (i.e., avoids the time lag to see the actual impact of implementation) and the risk of BMP implementation on a large scale (Rotz and Veith, 2006).

4.2.2.1 Monte Carlo Simulation

Monte Carlo simulation is a specific form of simulation that creates "artificial futures by generating thousands and even hundreds of thousands of sample paths of outcomes and analyzes their prevalent characteristics" (Mun, 2006, p.73). This method can be used to determine how random variation, lack of knowledge or error affects the performance, sensitivity and/or the reliability of a system. In a study such as the current one, it can be used to encompass historical data of model inputs to build distributions representing that data in an effort to portray potential outcomes (i.e., a distribution) that can be expected. Figure 4.2 depicts this process where x_n are the set of inputs which in this study could include historical crop prices or a distribution of weather events.

Figure 4.2 - Illustration of distributional inputs and outputs for Monte Carlo Simulation



Source: Wittwer (2004)

These inputs are represented by distributions of possible values, from which specific values are drawn for use in the simulation calculations. Desired outputs, y_n , are also distributions. In the context of the current study these may include cash flows, net present values, etc. that are used to answer the study questions.

In its simplest form, Monte Carlo simulation is a number generator that randomly draws from predefined probability distribution similar to those shown in Figure 4.2. It is a useful tool in a variety of fields of study. In the field of finance, Monte Carlo simulation is often used to calculate the value of companies, investment projects or to evaluate financial derivatives.

In this study, Monte Carlo simulation methods are used to replicate outcomes for a mixed farm in southern Alberta in an effort to understand the costs and benefits of BMP implementation. Simulation techniques are chosen over mathematical programming modeling because of the advantages with respect to flexibility; that is, the ability to incorporate complex relationships such as crop yield response, price expectations, etc. Monte Carlo methods are used because of the importance of stochastic elements (i.e., risk) related to production decisions and the resulting outcomes.

The specific program used to develop the simulation model is @risk for Microsoft Excel. This software is useful for Monte Carlo simulation as it expands upon the basic single point estimates calculated within standard Excel spreadsheets. The underlying idea behind the software is that every action in a decision is potentially risky, whether that be an investment decision or otherwise. If risk can be quantified, in terms of determined outcomes and probabilities of occurrence, then a probability distribution can be used to summarize this risk within the spreadsheet (Palisade Corp., 2007).

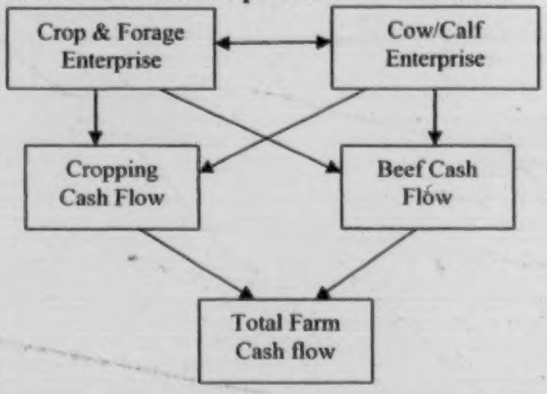
Descriptively, the simulation model developed using this software outlines current operational practices at the farm level and can be manipulated to suggest refinements in practice in terms of BMP implementation. Risk analysis is performed through simulating all possible outcomes based upon the sources and magnitudes of risk identified in the spreadsheet. The model is solved iteratively in that the computer recalculates the values in the worksheet repeatedly for different sets of stochastic parameters drawn from the specified input distributions (Palisade Corp, 2007). Each "iteration" produces values for all output variables. After the simulation is complete, the @risk output provides a complete picture of all possible outcomes including the best and worst case scenarios through the distributions of outcome variables. These distributions are then compared between different BMP scenarios to assess the impact of adoption for these practices.

4.3 Lower Little Bow Simulation Model Structure

The first step in the process of understanding the biophysical and economic results of implementing BMPs was to build a working simulation model. A model was needed that defined all the basic working relationships within a farming operation. This model needed to be able to represent a mixed farm with crop, forage and livestock production along with all the relationships or links between the different enterprises. These relationships were both economic and biological in nature.

Directly tied to production, economic relationships regarding costs and revenues had to be connected. Basic input costs include expenses for inputs such as seed, fertilizer, trucking, labour, etc. Basic revenues are the product of crop and beef production and prices. However, further costs and revenues are realized through participation in government programs such as crop insurance and the Canadian Agricultural Income Stabilization (CAIS) program. The magnitude of these costs and revenues are dependent upon the biophysical interaction between weather, crop, forage and livestock production. Producer crop revenues are a result of crop yields realized at the end of the growing season and those crop yields are correlated to the weather patterns in that season. Producer livestock revenues are an outcome of calf weights at the end of the grazing season. The length of the grazing season and pasture productivity are also tied to weather. The following diagram, Figure 4.3, shows the general bio-economic simulation structure.

Figure 4.3 - Model of bio-economic relationships within a mixed farm



Within Figure 4.3, each enterprise is assumed to be separate in terms of having unique decision variables which are simulated to produce outputs in the form of enterprise revenues and expenses. There are alternative measures which may be used to represent these flows, including gross margin (GM) or net cash flow (NCF). A GM is defined as revenue net of the cost of goods sold. The cost of goods sold are variable expenses directly related to the production of goods sold by a company. Thus the GM represents the margin that remains to contribute towards fixed costs. NCF is the difference between all cash inflows and cash outflows for the enterprise (or business). It includes items that are costs (including some fixed costs) as well as items that are not costs but are expenditures (e.g., principal portion of debt servicing payments). For reasons that will be outlined in the next chapter, an alternative measure, referred to as modified net cash flow (MNCF), is used. This cash flow measure includes more than would be included in a gross margin calculation but does not cover all expenditures that would lead to a true net cash flow calculation. Chapter 5 provides a detailed description of some of the variables included in the MNCF calculation.

All parts of the model affect a number of other aspects of the model in numerous ways. Within the crop and forage enterprise part of the model, decision variables include what crops and forage to grow, in what rotation and on how much land. These are incorporated into the simulation model and are combined with parameters such as crop prices and weather to produce an economic output. At this level, there are both predefined factors that will impact the farm over the time period and stochastic parameters that are not predefined and change randomly throughout the simulation. The weather and price variables for a particular year are the result of random draws from distributions based on historical data. The weather impacts crop yields to the extent that a drought or a flood will decrease yields and good weather will result in good or expected yields. These yields combined with simulated crop prices will produce crop revenues, an output that is realized at the end of each year. Forages produced will be used to feed the herd over the winter months. If forage yields are high based on simulated weather, excess inventory can be sold. If the opposite is true, then the beef enterprise is forced to purchase feed from the market. Therefore, there is a relationship between the crop and forage enterprise and the beef enterprise and beef MNCF.

The beef enterprise includes any process related to raising livestock in a cow/calf production setting. A detailed description of this enterprise can be found in Chapter 5. Similar to the crop and forage enterprise, revenues and costs are directly related to predefined and external variables including herd dynamics, beef prices and weather. Weather is simulated and impacts the length of grazing seasons from year to year; that is, weather may shorten or lengthen the grazing season. Any change in the grazing season will affect the amount of forage needed to feed the herd over the winter months. A short growing season will increase the demand for forage and vice versa. This will impact the crop and forage enterprise by decreasing or increasing the inventory that can be sold affecting forage revenues. The two MNCF's for each enterprise are then combined to create a modified net cash flow for the entire operation and this will be used as the comparator in the study.

This study focuses on the economic implications of best management practice adoption therefore the model includes relationships between BMPs and farm enterprises. The process is similar to what is described above with the exception that there are additional decision variables for the producer. These decision variables are the BMPs to be implemented within each enterprise. The BMP options available are dependent on what enterprise is chosen. For instance, off-stream watering is an option for the cow/calf enterprise but not for the crop enterprise for obvious reasons. These BMP decisions in turn will affect the separate enterprise decisions. The BMP of converting cropland to permanent cover will affect the acreage that the user will plant crop on.

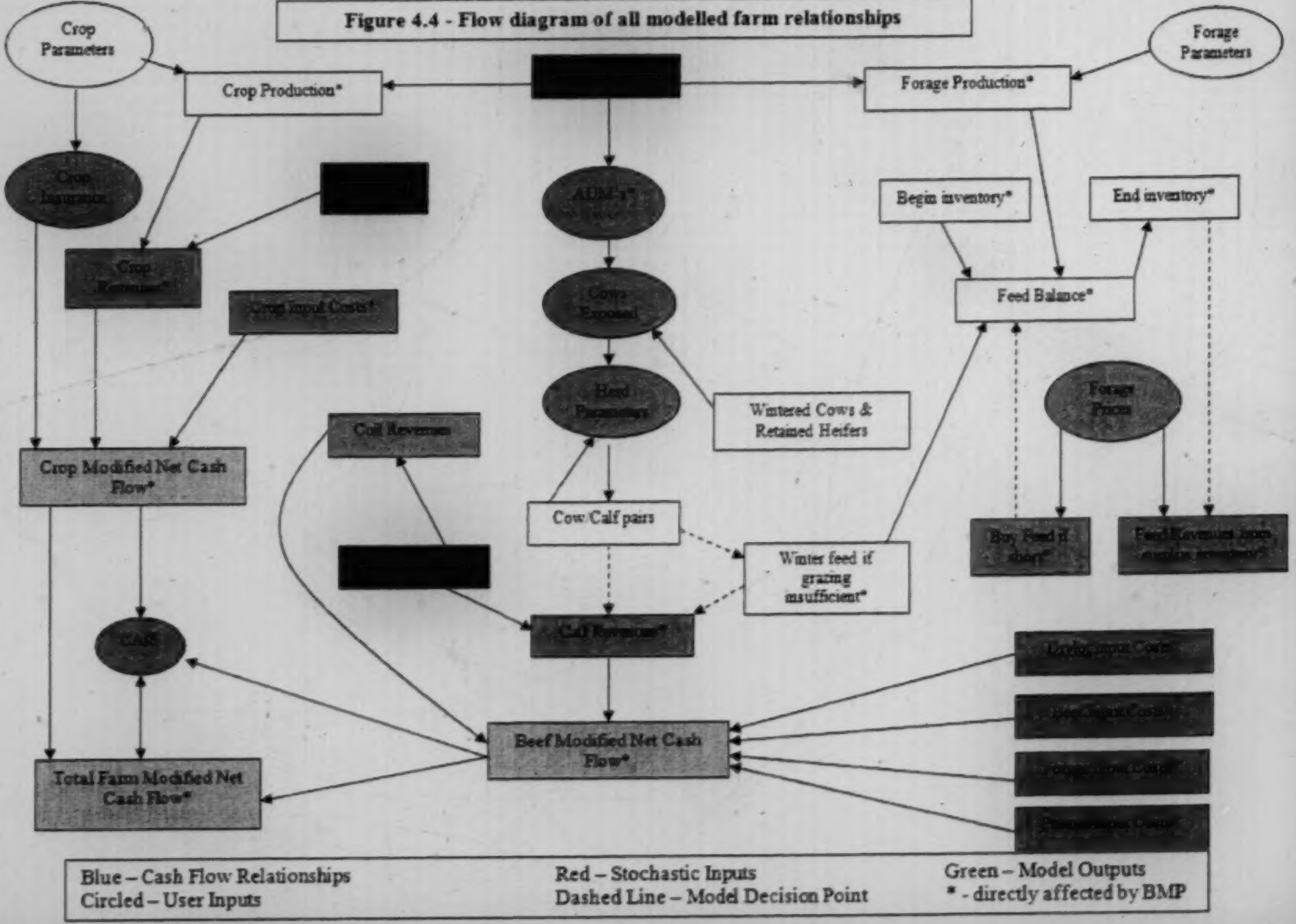
Figure 4.4 shows the complete simulation model structure including the relationships between all the components of the representative farm. The circled objects represent the predefined variables for both enterprises that are set before simulation occurs. Some of these include the crop insurance protection levels, acreage allocated to crop and forage production and the dynamics of the cow/calf herd. Objects shaded in red are stochastic variables that continually change over the simulation defined by probability distributions to force outputs to be calculated and shown as probability distributions. Objects shaded in blue represent cash flow relationships that are used directly in the calculation of outputs in the form of modified net cash flows which is shaded in green. Objects labelled with an asterix are directly impacted by BMP implementation. Dashed lines represent model decision points that are dependent on numerous relationships occurring in the model and these will be further explained in the following chapter.

4.4 Chapter Summary

This chapter discusses the advantages and disadvantages of alternative modeling approaches that can be used in this study. An argument is made for the use of NPV and simulation analysis in studying the economic costs and benefits of BMP implementation. The strengths of NPV analysis include its ease of implementation and the ability to easily compare different investments decisions with a single value. Simulation analysis is the tool used to obtain these NPV statistics due to the ability to model most, if not all, the economic and biophysical relationships that are present at the farm level. Simulation works over space and time and replicates and forecasts relationships with the avoidance of large financial commitments, large time commitments and large risk. The simulation model is made operational through the use of @risk for Microsoft Excel.

The complexities and details of the stochastic simulation model structure were also outlined in this chapter. Stochastic variables, whose values are drawn from pre-specified distributions of values, include crop prices, beef prices, and weather. These values represent the non-systematic risk that any farm is exposed to and are the main influence in the estimation of financial return volatility for the farm. This volatility estimation along with CML theory will be used to determine an appropriate discount rate for the representative farm.

Figure 4.4 - Flow diagram of all modelled farm relationships


Crop Parameters
Crop Production*
Forage Production*
Forage Parameters
Crop Insurance
Crop Revenue*
Crop Input Costs*
AUM's*
Cows Exposed
Herd Parameters
Begin inventory*
End inventory*
Feed Balance*
Wintered Cows & Retained Heifers
Forage Prices
Crop Modified Net Cash Flow*
Cull Revenue
Cow/Calf pairs
Winter feed if grazing insufficient*
Buy Feed if short*
Calf Revenue*
CAIS
Beef Modified Net Cash Flow*
Total Farm Modified Net Cash Flow*
Blue – Cash Flow Relationships
Circled – User Inputs
Red – Stochastic Inputs
Dashed Line – Model Decision Point
Green – Model Outputs
* - directly affected by BMP

Chapter 5 : The Representative Farm and Empirical Simulation Model

This chapter details the specifics of the representative farm in the Lower Little Bow and the stochastic simulation model that was produced to analyze the economic costs/benefits of best management practice implementation. All aspects of the representative farm were incorporated into the simulation model from the size of the land base for annual crop, hay and silage production and livestock pasture to the specific dynamics of the cow/calf herd. The representative farm model was developed in Microsoft Excel which allowed for straightforward modelling of all appropriate relationships found at the farm level. As described in the previous chapter, simulation analysis generates an understanding of a system's performance and its response to uncertainty. In this case, that system is the mixed farm operation in the Lower Little Bow. The use of simulation software (ie., @risk for Microsoft Excel) provides the opportunity to model the farm dynamics through time incorporating uncertainty. This uncertainty comes in the form of stochastic crop prices, beef prices, and weather events which lead to stochastic crop yields. @risk randomly draws a price or weather event to create a farm outcome and does this repeatedly to form a distribution of outcomes.

Economic net present value analysis (NPV) was the key output used to compare the results of any costs or benefits associated with BMP implementation. NPV analysis was performed over a 20 year time period calculating a modified net cash flow (MNCF) for the farm operation for each year. MNCF was introduced in the last chapter and is described in detail in this chapter. The details of farm revenues and expenses are explained later in this chapter as well as the monetary relationships between the farm and government payment programs.

5.1 Representative Farm Characteristics

The following section outlines the characteristics of the farm in the Lower Little Bow. All physical features presented are based on the actual farm that is operating in southern Alberta. This section is divided into three main components describing the *crop and forage enterprise*, the *cow/calf enterprise* and the linkage between the two which is *feed inventory*. The data and statistics used to build the representative farm were provided by Agriculture and Agri-Food Canada (Ross, 2007) and Alberta Agriculture and Food (Kaliel, (2007); Pearson, (2007)).

5.1.1 Summary of Farm Land Base

The acreage covered by the representative farm is 12,640 acres. Of this acreage, 2240 acres (18%) is allocated to annual crop production, 1280 acres (10%) is allocated to forage production and the remaining 9120 acres (72%) is allocated as grazing pasture for livestock. Forage is defined as hay and silage produced that is used for winter feeding of the beef herd. The farm is larger than the typical farm for the county of Lethbridge as its acreage puts this farm in the top 6.4% of farms by size in the county (Table 3.1).

The land base for annual crop and forage production can be broken down into specific acreages for crop types. Table 5.1 shows the acreage by crop, forage and pasture type. The annual crops are representative of the major crop types found in the county (Figure 3.3 and 3.4). The representative farm is deemed a 'mixed farm' which is involved in grain and oilseed production as well as livestock production. Along with supplying adequate pastures for a large cow/calf grazing herd, a large focus has to be placed on being able to produce and store adequate amounts of winter livestock feed for the Alberta winters. The major feeds produced are greenfeed, hay and barley silage.

Native pasture, also termed native range, is land that provides grazing for livestock and wildlife that hasn't been cultivated, fertilized or irrigated. Conversely, tame pasture involves establishment and maintanence of a high proportion of introduced forage species (ASRD, 2004).

Table 5.1 - Summary of farm acreage

Crop	Acreage	Forage	Acreage	Pasture	Acreage (AUM)
Durum Wheat	160	Barley Silage	800	Native Pasture	7840 (0.26)
Spring Wheat	640	Alfalfa Grass Mix	480	Tame Pasture	1280 (1.54)
Barley	960			Aftermath Grazing	1480 (0.53)
Canola	480				
Total	**2440**		**1280**		**9120**
Farm Total	**12,640**				

Source: Ross (2007)

5.1.1.1 Crop/Forage Production and Rotation

The importance of implementing optimal crop rotations for productivity and competitiveness has been well researched. The crop rotation decision involves discovering and exploiting beneficial interrelationships between individual crops (El-Nazer, 1986). Yearly crop rotation can improve soil tilth, conserve plant nutrients and may help manure and chemical fertilizers be more effective (Crisostomo, 1993). There is no predefined crop rotation in the model in terms of which annual crops are planted following each other over time. In other words, the model does not track which crops are grown on specific parcels of land in each year of the simulation. Instead, the model allocates the acreage shown in Table 5.1 to each crop and the yields are not dependant on what crop was planted in the previous year. Implicitly, it is assumed that a crop rotation is implemented using durum wheat, spring wheat, barley and canola.

Furthermore, there are proven benefits to including forages, such as hay, in a commercial crop rotation. These benefits include reduced soil erosion (Stinner and House, 1989), suppression of weeds (Harvey and McNevin, 1990), increased soil organic matter (Blackwell et al., 1990) and the disruption of plant disease. Entz et al. (1995) surveyed Saskatchewan farmers and 71% of respondents reported a yield benefit from adding forages to their crop rotations. Within the farm model forages are produced for livestock feed purposes along with the annual crop production. Forages included are alfalfa-grass hay, barley greenfeed, and barley silage.

5.1.1.1.1 Hay and Greenfeed Rotation

The term greenfeed is used to describe the harvesting of a cover crop for livestock feed before permanent forage is established. Cover crops add nutrients and organic matter to soil and protect the early development of forages from the physical elements. It is also known as 'green manure' in this sense (Sullivan, 2003-a). A cover crop can be a mix of a cereal grain such as oats or barley with an underlying forage legume such as alfalfa or clover. The nutrients that are returned to the soil prepare it for a full forage stand that may be present for up to seven or eight years. The cover also provides physical protection for the underlying forage from physical elements as it establishes its root system for subsequent years of production.

There are economic benefits to cover crops in the form of nitrogen savings (Sullivan, 2003-a). Adding a nitrogen fertilizer to a cover crop such as barley may produce a yield that chokes the establishment of the underlying forage growth. Some forages such as alfalfa are nitrogen fixing meaning that they can meet nitrogen needs from natural sources. Thus there is no need for extra fertilizer. Without fertilizer, the barley cover crop may not yield as high as it otherwise would but future forage productivity is maintained. Long term, indirect benefits occur from the build up of organic matter leading to improved soil health and better yielding crops (Sullivan, 2003-a). According to a survey performed on 253 Manitoba and Saskatchewan producers, ninety percent of them used a cover crop consisting mostly of wheat or barley (Entz et al. 1995). On the representative farm, before the alfalfa-grass stand is seeded, there is an establishment of a barley cover crop.

Hay has historically been used as an off-season food for livestock and is a major feed source for cattle. It is produced from a variety of plant species including grasses and/or alfalfa. The advantage of producing hay is its storage life. If hay can be cut and baled at an appropriate moisture level (12-20% moisture), it can be stored for long periods of time and still be used as a primary feed source for livestock (AARD, 2005). Harvesting forage can occur multiple times over a grazing season. Brown and dark brown soils zone, similar to those found in the Lower Little Bow watershed can produce one to two cuts of forage over a grazing season. (AAFC, 2003-a) A mix of alfalfa and grass forages, referred to as alfalfa-grass hay, is used to produce hay on the representative farm.

A large factor in determining appropriate crop management strategy is the soil type that is present on farms. Black or gray soil zones leave an adequate amount of nitrogen for the following cereal or oilseed that is seeded after a forage stand (Hoyt and Leitch, 1983). However, in dark brown soil zones there is often a moisture shortage after an alfalfa stand (Brandt and Keys, 1982). The Lower Little Bow Watershed includes both dark brown and brown soil zones[3]. An option for a producer to replenish moisture is to fallow the fields after the final year of the forage stand. This management strategy is popular in the area, as outlined in section 3.2 and shown in Figure 3.5.

Research has shown the benefits to various stand lengths ranging from as short as three to four years up to as long as seven years (Entz et al. 1995). In Saskatchewan, the average forage stand length is 6.5 years (Entz et al, 1995). Jeffrey et al. (1993) examined the economic implications of including varying lengths of alfalfa stands in cereal-based rotations in Manitoba. Results concluded that 5 years was the optimal stand length in terms of the profitability of the rotation. Campbell at al. (1994) found that a six year alfalfa stand had much higher nitrogen trace level than a three year alfalfa stand. No matter what the forage stand length is, the value of legumes such as alfalfa in a crop rotation has been recognized (Bruulsema, 1987). Table 5.2 displays the forage rotation on this farm. Year one is the establishment year utilizing a cover crop, years two through six produces alfalfa/grass mix hay. In year seven, the management strategy of summerfallow is utilized. However, an early season crop is removed so not to lose all production in that year. After the first cut is taken in year seven, the fields are fallowed.

Table 5.2 - Forage stand progression

Year	Forage
1	Greenfeed (Barley Cover Crop)
2	Alflalfa-Grass Mix
3	Alflalfa-Grass Mix
4	Alflalfa-Grass Mix
5	Alflalfa-Grass Mix
6	Alflalfa-Grass Mix
7	Fallow (First cut taken)

Annual forage stand yields tend to increase over time after establishment, before decreasing again. Thus any forage stand does need to be removed from a field after a certain period of time. Renovation becomes necessary due to autotoxicity, seedling disease and pest build-up that can occur in old forage stands (Bagg, 2001). Autotoxicity is the reduction of growth of new alfalfa plants due to the production of toxins.

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[3] Map of Alberta's soil zones found in appendix B.

Medicarpin is a compound produced by alfalfa and this compound delays alfalfa seed germination and slows seed growth from year to year (Dornbos Jr et al., 1990). This trend in yields was recognized as important and was modelled in this study. Leyshon et al. (1981) studied the effects of seeding rates and row spacing of forage crops in southwestern Saskatchewan. Dry matter yield for a five year alfalfa/grass stand was measured to determine the percentage change in forage yield over the lifespan of a hay stand and these values are used in the simulation model. Table 5.3 displays the results from Leyshon et al. (1981). The alfalfa grass yield in year one was 10% higher than the five year average mean yield whereas the yield in year five was 53.88% below the five year mean yield. This trend is accounted for when simulating crop yields in the simulation model. The actual yields used in the simulation are drawn from stochastic distributions, discussed later in this chapter.

Table 5.3 - Alfalfa/Grass variation by year of stand

Year	% Yield Differential Relative to the 5 Year Mean
1	+10.00%
2	+34.20%
3	+20.38%
4	-14.98%
5	-53.88%

Source: Leyshon et al. (1981)

5.1.1.1.2 Silage

Silage is a form of high moisture feed, usually oats, corn or barley, that is fermented in anaerobic conditions for preservation. A forage crop is harvested and chopped into pieces, ideally 0.5 inches long, and packed in silage piles or stored in silos to remove oxygen. The removal of oxygen begins the fermentation process which in essence 'pickles' the feed allowing it to be stored for long periods of time without reducing feed quality. A much larger proportion of the nutrients are preserved in silage production compared to hay production (AARD, 2004). However, it is much costlier to produce silage and much of the storage costs are directly related to moisture content. Ideal silage has a moisture content of 55% to 65% for optimal fermentation and feed quality. Therefore much of the storage capacity is taken up by water (AARD, 2006-a). In

Alberta, 61% of total silage production was in the form of barley, 18% came from oats and the remainder from mixed grains and grasses (AARD, 2008-a). The representative farm utilizes barley for silage production.

5.1.1.2 Pastureland Management

The land base allocated to the cow/calf enterprise comprises 87% of the total land base for the farm (Table 5.1). This land includes pasture land and forage production acreage. Pasture land is used for grazing animals such as cows and is used extensively in cow/calf operations. This land does not go through a rotation like crop and forage land due to the large acreage and the difficulty of moving pasture. Pasture land on this farm can be broken down into two types: tame pasture and native pasture.

As mentioned previously, native pasture has not been altered in any way to provide grazing for livestock and wildlife whereas tame pasture typically includes vegetative species not normally found in the area. These introduced species can include brome and timothy grass, alfalfa, clovers, red fescue, quack grass and/or kentucy blue grass. Native species that are found in Alberta include peavine, vetch, hairy wild rye, march reed grass, rough fescue and native wheat grasses (ASRD, 2004). The major difference between native and tame pasture is that native pasture grows much more slowly than tame pasture (AARD, 2007-c). Therefore, different management strategies need to be undertaken to maintain healthy pastures over time. Some of these strategies include grazing tame pasture early in the spring to allow for adequate native pasture growth into the summer months. On the representative farm, tame pasture makes up only 14% (1280 acres) of total pasture acreage while the remaining 86% (7840 acres) is native pasture.

5.1.2 Cow/Calf Enterprise

The large land base that is available provides the farm with the ability to support a large cow/calf herd. A complete summary of the cow/calf herd statistics is can be later found in Table 5.4. The following sections outline the important relationships, definitions and dynamics associated with the cow/calf herd. The complexity of a cow/calf operation lends itself to specific modelling in order to be representative and confident in modelling outcomes. Some of these intricacies include how, when and the intensity of pasture grazing, herd management whereby old or sick animals are replaced by young and healthy animals and feeding regimes for the herd.

5.1.2.1 Herd Grazing

Stocking rate is one of the most important decisions that a cow/calf producer has to make in a grazing season (Willms et al., 1985). The stocking rate is the amount of land that is allocated to each grazing animal over a certain period of time. In the beef production cycle, the majority of weaned heifers or steers that are to make their way to feedlots have gained weight on pasture. Mismanagement of pasture utilization and stocking rates can lead to inefficiencies in getting calves to the optimal weight for sale. The main goal of a producer in pasture management is to keep costs down by grazing longer (AARD, 2008-b). However, a longer grazing season should not come at the expense of future pasture productivity. Forage production depends on soil and climatic conditions as well as pasture conditions. Therefore, stocking rates need to be determined for each field each year for optimal management (AARD, 1998). The large size of the herd in the Lower Little Bow makes this an even more important decision. The starting herd size used in the model is 464 animals, including all cows and first-calf heifers[4] and bulls.

The stocking rate is a term used to describe pasture productivity and is measured using the Animal Unit Month (AUM). An AUM is the amount of forage required per month by one animal unit (AU). One animal unit is defined as a 1,000 pound beef cow with or without a calf. This cow or pair has an assumed daily feed requirement of 26.2 pounds of dry matter forage which equates to a monthly requirement of 799 pounds of dry matter forage (AARD, 1998). The stocking rate then, is most often expressed as a value in terms of AUMs/acre. An example of this calculation is as follows: If 160 acres has been able to support a 30 cow herd for 4 months without degrading pasture conditions over the growing season, the quarter section has a stocking rate of 120 AUMs (30 animal units*4 months). On a per acre basis, this pasture has a productivity of 0.75 AUMs per acre (120 AUMs/160 acres) (AAFC, 2003-c). Carrying capacity then, is the average number of cows that can be placed on pasture over a grazing season without degrading its condition. Referring to the above example, the carrying capacity of the 160 acre pasture is thirty 1000 pound cows and their suckling calves. This carrying capacity would change if cow weights are different. The animal unit equivalent (AUE) accommodates this possibility. If animal sizes vary, so does the forage requirement. A cow weight of 1500 pounds has a AUE of 1.5 meaning that the forage needed for this animal is 1.5 times that of a 1000lb cow. A bull is assumed to have an AUE of 1.4 times that of cows.

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[4] A first calf heifer is a termed used to describe a young cow that has only had one calf.

In this study, the average cow weight is assumed to be 1200 pounds. The pasture productivities for upland areas of tame and native pastures on the representative farm on a per acre basis are 1.54 and 0.26 AUMs, respectively (Table 5.1).

As outlined in earlier chapters, riparian areas provide an abundance of forage and are often much more productive than uplands due to the high water table (Fitch and Adams, 1998; Bork et al., 2001). Management strategies need to differentiate between grazing upland pasture and riparian areas, as the latter is much more susceptible to damage. The impact of livestock grazing has profound effects not only on vegetation, but stream bank stability, water quality, etc. Studies on riparian ecosystem productivity have concluded that riparian areas can produce double the amount of vegetation produced in upland areas (Asamoah et al., 2004; Unterschultz et al., 2004; Bork et al., 2001). It has become normal for producers to assume that riparian pastures have double the productive capacity of upland areas (Soulodre, 2007). Consequently, riparian area productivity in tame pasture was initially assumed to be 3.08 AUMs/acre, and 0.52 AUMs/acre for native pasture.

Another grazing practice that has become common in southern Alberta is to graze crop aftermath. Crop aftermath consists of the crop residues that remain after harvest. Specifically, husks, chaff and grains from combining or other harvesting techniques make up crop aftermath residue (Graves, 1982). They can be utilized with supplemental feeding and can supply a considerable portion of the total energy needs of cattle (Males, 1987). It is assumed that the entire land base allocated to crop production is subsequently used for aftermath grazing for the cow herd. The productivity of the aftermath grazing pasture is 0.3 AUMs/acre (Table 5.1) (Ross, 2007).

5.1.2.2 Herd Dynamics and Production Cycle

Herd dynamics are used to describe the specific physical characteristics of how the cow/calf herd acts and evolves throughout the production cycle. In this study, the production cycle starts at the time a cow or heifer is bred, moves to calving and then onto weaning. Table 5.4 shows the pertinent cow/calf statistics that are utilized in the model to simulate the beef production cycle. The total herd size is 488 animals including cows, replacement heifers and bulls which is representative of the farm in the Lower Little Bow. Replacement heifers are animals that have not yet had a calf and are retained by the producer to replace cows that are removed or culled from the herd. All statistics found in Table 5.4 are explained in depth in the following sections.

Table 5.4 - Cow/calf herd statistics

Basic Herd	400
Replacement Heifers	64
Bulls	24
Mean Cow Weight (lbs)	1200
Conception Rate (%)	89.0
Calving Rate (%)	98.0
Weaning Rate (%)	97.0
Cow Death Loss (%)	1.0
Calf Weight Gain (lbs/day)	1.65
Desired Calf Market Weight (lbs)	550

Source: Ross (2007)

5.1.2.2.1 Breeding, Calving and Weaning

Calving and breeding seasons were predetermined and set to specific months. Breeding occurs in the month of June. The breeding is performed on cows or heifers that have been raised on the farm. However, not all animals will be impregnated and follow through to produce a calf. This is represented by two production statistics that are applied to the herd. The conception rate and calving rate have been estimated for cow/calf producers in southern Alberta, and are approximately equal to 89.0% and 98.0%, respectively (Kaliel, 2007). The conception rate is the percentage of animals that become pregnant after breeding and the calving rate is the percentage of animals that, once confirmed pregnant, give birth to a calf at the end of gestation. These values account for miscarriages and calving difficulties leading to calf death.

Calving season occurs nine months after breeding in February. Calves stay with their mother throughout the grazing season until they are weaned[5]. The possibility of calf loss over the grazing season is factored in as well. This loss may be due to nutrition deficiency, health or mothering problems, or predator loss. The probability that the calf survives the grazing season, otherwise known as the weaning rate, is approximated to be 97.0% (Kaliel, 2007). A cow death loss statistic was also included and set at 1.0% (Stillings, 2000).

It was decided that a daily weight gain of 1.65 pounds/day would be assumed to achieve a desired minimum weaning weight of 550 pounds. Summary statistics for the actual herd on the Lower Little Bow confirmed that this value is accurate. Actual data for farm steer and heifer selling weights suggested average weights of 560 pounds and 532 pounds, respectively (Kaliel, 2007). Even though the desired selling weight is 550 pounds, the simulated selling weights were not the same however from year to year. Due to the stochastic nature of the simulation model, calf selling weights were directly related to grazing season length and other decision variables. The desired calf market weight was 550 pounds coming off of grazing. However, depending on the weather patterns in a particular year, the actual weight at the end of the grazing season may be greater or less than 550 pounds. For example, a short grazing season could result from a lack of moisture. The moisture shortage reduces AUM's available for the herd and thus forage is completely consumed in a shorter period. This results in lower calf weights once grazing is exhausted.

If the calf weights are below 550 pounds off pasture, then calves are assumed to be fed in a drylot until the desired weight is reached. The calves are then sold at the simulated price for heifers and steers. Conversely, if calves reach the desired market weight and there is still grazing available, calves are kept on pasture until grazing is depleted. This results in the selling of calves that are over 550 pounds. Once all grazing pasture forage has been consumed, heifers and steers are sold at the respective simulated prices for that year. It is common practice for producers to keep calves on pasture for as long as possible to attain the highest possible calf weights.

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[5] Weaning is the process of removing a calf from its mother.

5.1.2.2.2 Cull Cow and Replacement Heifer Management

After calves are weaned, steers and most heifers are sold to either backgrounding or feedlot operations. To maintain a steady herd size with healthy animals, cow/calf producers must retain and raise some heifers for future breeding and calving. Old cows that have become prone to reproductive problems or have other maintenance requirements are sold. These are known as cull cows.

Any cow that does not conceive at breeding or have a calf at the end of the grazing season will be culled. The number of cows that are to be culled each season is a function of the herd statistics from breeding to weaning described in the previous section. Consequently, the culling percentage for this operation is approximately 16% per year. In other words, 16% of the herd including cows and/or heifers are culled each year. Culls are sold at two separate times. Cows and/or heifers that do not conceive are sold after breeding in July. Those cows and heifers that do conceive but do not produce a calf at the end of the grazing season are also sold as cull animals. For each animal that is culled in a production year, a replacement has to be brought into the herd to maintain the herd size. This animal will be a replacement heifer that was retained after weaning and it will be brought into the herd once breeding commences the following year. Hence, the number of heifers that are retained for replacement is also a function of those herd statistics and has to be greater than or equal to the 16% of the herd which are lost each year.

Replacement heifers are weaned at the end of the grazing season and sent to the drylot operation. The drylot is in essence a backgrounding operation where heifers are fed a particular diet separate from the rest of the herd until they reach sexual maturity and can be bred to replace the animals lost to culling. Proper feeding during this time is crucial for the animal's development (AARD, 2007-a). These replacement heifers are fed over the winter and in June, they are bred with the rest of the herd. As noted earlier, the drylot is also used to winter feed market steers or heifers that did not reach the desired market weight over the grazing season.

5.1.2.2.3 Bulls

For a large herd like the one found in the Lower Little Bow, utilizing herd bulls is the most effective breeding practice. Alberta Agriculture and Rural Development (2007-

a) suggest that one bull can service 12 to 15 cows depending on the maturity of the bull. The farm in the Lower Little Bow has 24 bulls for the entire herd which is 1 bull for every 19 cows and/or heifers. When old bulls are culled, new bulls are purchased and brought in on a yearly basis.

5.1.3 Winter Feeding and Feed Inventory

The link between the crop enterprise and cow/calf enterprise comes in the form of feed produced on cropland and then fed to livestock through winter feeding. Greenfeed, hay and barley silage are produced over the growing season and then stored and fed to cows, heifers and possibly market steers and heifers over the winter season. The length of winter feeding is a result of the length of the grazing season. If the grazing season is longer, then the length of time over which winter feeding occurs is shorter. The demand for winter feed is based upon the number of animals that are being winter fed and the respective diet required by those animals. Table 5.5 outlines the diet for different livestock groups. The table is representative of the approximate feed requirement for beef animals in southern Alberta. These daily requirements for cows, bulls, replacement heifers and winter calves were obtained from Alberta Agriculture and Food (Kaliel, 2007; AARD, 2007-b).

Table 5.5 - Winter feed diet (pounds of dry matter/animal/day)

Feed Type	Cows	Bulls	Replacement Heifers	Winter Fed Market Calves[a]
Hay/Greenfeed	24.07	26.00	1.78	7.00
Barley Silage	6.63	9.10	20.47	11.50
Supplements	0.1	0.15	0.26	-

a: Winter fed market calves are those that do not meet the desired market weight of 550lbs at the end of the grazing season and are fed in the drylot until this weight is reached.

The values in Table 5.5 from AARD are calculated on a dry matter basis. Feed production simulated in the model is calculated on a wet matter or "as fed" basis meaning that it accounts for an assumed moisture content of the feed. Therefore the calculation of the supply of feed necessitated a conversion to a dry matter basis. As described in sections 5.1.1.1.1 and 5.1.1.1.2, Alberta Agriculture and Food estimates the optimal moisture level of hay and silage to be from 12% to 20% and 55% to 65%, respectively.

Therefore, the total yield for hay/greenfeed and silage was adjusted by 15% and 65%, respectively, to obtain a dry matter yield. Hypothetically speaking, if 10,000 pounds of hay is produced at a 15% moisture level, then the dry matter equivalent available for livestock is 8,500 pounds (10,000*(1-0.15)). This calculation is the same when calculating dry matter silage using a 65% moisture level. With silage production, there is a likely chance of spoilage and pit loss. Alberta Agriculture and Food estimates that loss to be 16% of total dry matter yield (AARD, 2006-c). Therefore, once the dry matter equivalent is calculated, it is adjusted downward by 16% to take into account pit loss and spoilage.

Depending on the yields that are realized over the grazing season, the supply that results may not be enough to meet demand. If this is the case, feed must be purchased at market value. In many years there may also be an oversupply of feed. Most often, producers keep as much feed as possible, if there is excess, as a risk management strategy (i.e., holding reserves). However, in southern Alberta, there is a market to sell excess feed to what is known as "Feedlot Alley". Southern Alberta has some of the largest feedlots in Alberta and the demand for silage and forage is so great in this area that many farmers take the opportunity to generate a new revenue stream by selling excess feed to feedlots. On that basis, it was decided that the farm would keep up to one year's worth of inventory in feed. Any excess is subsequently sold at market value. Holding this inventory protects producers from shortages in the following years. A drought year may significantly reduce the amount of feed that is able to be produced and subsequently fed. Holding inventory helps to reduce some of the effects of major crisis such as the recent BSE events[6] and drought.

5.1.4 Machinery Complement

A farm of this size includes a large equipment asset base for production activities. A general machinery complement sufficient to complete all farming tasks was "built" to represent the machinery asset base that would be found on a farm of this size[7]. A complete record of the machinery base for the representative farm was not available.

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[6] Producers who chose not to sell animals at very depressed prices held onto animals longer than normal resulting in higher feed needs for the larger herd sizes.

[7] The complete machinery complement is provided in appendix C.

Cortus (2005) outlines two alternative methods to determine a representative machinery complement. One process is to use a machinery complement selection algorithm. Oklahoma State University utilizes its Optimum Machinery Complement Selection System (OMCSS) to solve least-cost machinery complements for different production systems. This program can select machinery combinations that minimize the total cost of performing specific field operations in a specific time period (Epplin et al., 1982). Reid and Bradford (1987) developed a multi-period mixed integer programming model (MMIP) for optimal machinery decisions. The model acknowledged the opportunity costs associated with machinery investment decision including financial constraints and machinery capacity.

However, Rotz et al. (1983) explain that reality often differs from the "optimal" machinery complement as farms usually exhibit a much a larger machinery base than it is needed, so it is difficult to model a precise machinery complement for any farm. While there may be a variety of reasons that producers would maintain a larger machinery base than would be suggested by these optimizing models (e.g., prestige), one economic reason relates to risk management. For many producers, there is a limited "window" available for completing some types of machinery tasks (e.g., tillage or harvest). As well, this window is weather dependant and thus stochastic. Therefore, an appropriate risk management response by producers would be to choose a larger machinery set to reduce the likelihood of not being able to complete machinery tasks in a timely fashion.

Given the time horizon of this study, representing machinery replacement in the model had to be addressed and there are many replacement strategies that a farmer can use as a decision rule to decide when and how to buy and replace equipment[8]. The processes described above for optimal machinery replacement strategies were beyond the scope of the current study but one strategy was required. Resultingly, this study follows Cortus' (2005) second approach by choosing a machinery complement in an ad-hoc manner where powered equipment was chosen on a horsepower basis to operate different types and sizes of drawn equipment. There was no specific information regarding the machinery complement of the representative farm so a machinery base had to be chosen that would closely represent what would be found on a farm of that size. The machinery base was chosen on the basis of recognizing which farming activities were prevalent for the beef, crop and forage enterprises. One piece of machinery could be used within two different enterprise (e.g., tractors) and these overlap possibilities were taken into account when deciding on a machinery complement.

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[8] A list of machinery replacement strategies is found in appendix D.

Given the time horizon for the simulation (i.e., 20 years), machinery replacement becomes an issue. However, explicitly modeling machinery replacement decisions within the simulation framework is somewhat problematic. The timing of the decision needs to be either arbitrarily determined or else a decision rule needs to be programmed into the model. As well, the variability in cash flows created by periodic machinery replacement may mask the impact of BMP adoption within the model. As a result, a simplifying assumption is made that the producer expends a constant amount of cash each year to maintain the value of the machinery complement. This constant amount would be spent on a combination of maintenance costs and machinery replacement. This constant amount spent each year to maintain the machinery complement is a function of the total asset value and essentially is calculated based on the depreciation rate for machinery.

In order to calculate this annual cash outflow, the asset value of the machinery complement must first be estimated. This was computed by finding current market values of the machinery. A few sources were explored for asset values. The first was the 2007 Machinery Cost Guide from Alberta, Agriculture and Food. This guide calculated the current replacement costs of various types of machinery depending upon horsepower and annual hours of use. The second was the Saskatchewan Agriculture and Food Farm Machinery Custom and Rental Rate Guide for 2006-2007. This performed the same calculation as the 2007 Machinery Cost Guide. The third source of equipment costs was the online farm machinery catalogue *Ironsearch.com*. This website allows producers and farm equipment dealers from all over North America to easily market equipment on-line to other producers and dealers. A producer can perform a broad search for equipment or define his or her search to a range of horsepower wanted, age of machinery, brand of machinery, location (province or state) of seller, etc.

It was decided that *Ironsearch.com* would be the source to attain the most representative machinery values. The provincial machinery cost guides were not used because of a significant assumption used in those publications. Specifically, they assume that the replacement cost of machinery is based on the price of *new* machinery which may overstate the actual asset value. Using those values does not incorporate the possibility of producers buying used equipment which would reduce the replacement cost. *Ironsearch.com* allows prices to be acquired for a type of machinery, new or used, allowing for a better representation of the range of replacement costs for certain machinery.

This search was defined to only include machinery located in Alberta. The search returned machinery at many different price and age levels. However, equipment that was built before the year 2000 was not included in asset calculations. This was done because of the size of the farm in this study. The acreage puts the farm in the top 6.4% (Table 3.1) of the farms in the county. Larger farms have the equity base and cash flows to acquire newer equipment easier than smaller farms that may not have the same financial base. The selling prices of equipment from the year 2000 to 2008 were averaged and that value was assigned to the asset to build the total machinery asset base.

The total machinery asset value was then subject to a depreciation rate which was used to calculate the annual machinery replacement cost for the farm. Depreciation is a measure of the loss of value of a machine over time. This depreciation stems from usage over the course of a year and the wear and tear that accrues on machinery from usage. Untershultz and Mumey (1996) estimated economic historical economic depreciation for combines and tractors. They found that combines have been depreciated between 7% and 9% depending on manufacturer and tractors have historically been depreciated between 4% to 8%, again, depending on manufacturer. A depreciation rate of 8% was used in this analysis.

5.2 Stochastic Implementation

As explained in Chapter 4, in modeling the representative farm all biophysical and cash flow relationships are directly affected by the stochastic elements of the simulation model. The stochastic nature of the model and the use of Monte Carlo simulation mimics the risk; more specifically, the production and market risk that is always present in primary agriculture. Without the acknowledgement and incorporation of risk, a study on agricultural production will not be a proper representation of reality. The stochastic process in this study amounts to a sequence of random values that are drawn from distributions of stochastic variables. These changing values are weather, crop prices and beef prices. Weather variability affects crop yields from year to year and changing beef and crop prices represent other sources of external price risk borne by the producer. These uncertain parameters are modeled over a 20 year time horizon and affect many elements of the farm including grazing season length, crop yields, farm revenues and costs and any payments from government programs. The behaviour of these stochastic elements is one of the main factors in deciding the economic feasibility of BMP implementation. This section provides a discussion of the estimation of these relationships and the empirical issues surrounding them.

5.2.1 Stochastic Weather

Weather is a critical driver that affects the profitability of agricultural producers through its effect on crop yield. Weather affects yields and farm output from the choice of crops planted and subsequent yield received (Plaxico, 1961). Dry years, like those experienced in Alberta from 2001 to 2003 have substantial impacts on farm performance for both crop and livestock producers. Limited snow accumulation leading to lower spring runoff resulted in low surface moisture in soils and low dugout and reservoir levels for most of the province (AAFC, 2006). Cooler temperatures persisted through the spring and summer which delayed pasture growth and seed germination. This crop stress resulted in lower yields and reduced feed production. The other end of the spectrum provides similar outcomes; excessive moisture in spring may delay the start of seeding or make it completely impossible to seed a crop at all. Excess moisture is also conducive to increased crop disease risk.

5.2.1.1 Weather Data and Calculations

In this study, the influence of weather is the main driver behind estimating crop yields but the impact of other explanatory factors has not been overlooked. There is extensive literature estimating yields of certain crops using explanatory variables other then weather. Kropff et al. (1991) simulated crop yields based on weed density, weed emergence and environmental conditions for three different crops. Simulation results concluded that analyzing the emergence of weeds after crop emergence had several advantages for management decision making and crop yield estimation. Heiniger et al. (1991) produced a model that predicted grain yields based on soil moisture levels and historical rainfall patterns. Results determined there to be significant yield reductions when soil moisture levels at seeding were below normal for the area and less significant losses when soil moisture levels were above the area average. Schroder at al. (1984) estimated corn yields in the corn belt region of the United States (Iowa, Illinois, Nebraska) using fertilizer, herbicides and genetic improvement from 1964 to 1979 as explanatory variables. Partial regression coefficients were derived from cross-sectional time-series data using a second degree polynomial function. Results showed that increased use of herbicide accounted for 20% of the increase in corn yields. Increased fertilizer use and genetic improvement accounted for 26% and 13% of the increases in corn yields, respectively.

Due to the lack of historical time series data for productive inputs (i.e., fertilizer, herbicides, etc) relating to historical crop yields for the study area, it was decided that estimating crop yields directly from weather in the form of growing season precipitation and growing degree days was most appropriate. Crop yields are directly affected by temperature and moisture conditions providing much of the risk involved in crop production. These data were readily available for the study area. Hence, growing season precipitation (GS) was used to represent moisture conditions and growing degree days (GDD) was used to represent temperature conditions. The implicit assumption is that producers use the right type of inputs (fertilizer, etc) and in the right manner to achieve yields, and actual yields are only affected by weather variability.

Growing season precipitation was represented as the total precipitation in millimetres that fell in the growing season for the area. For this study the growing season begins May 1st and ends October 31st which is representative of when seeding usually begins and harvesting ends for producers in the area (Smith, 2007)[9]. Figure 5.1 shows the historical growing season length from 1971 to 2000 for Alberta. The county of

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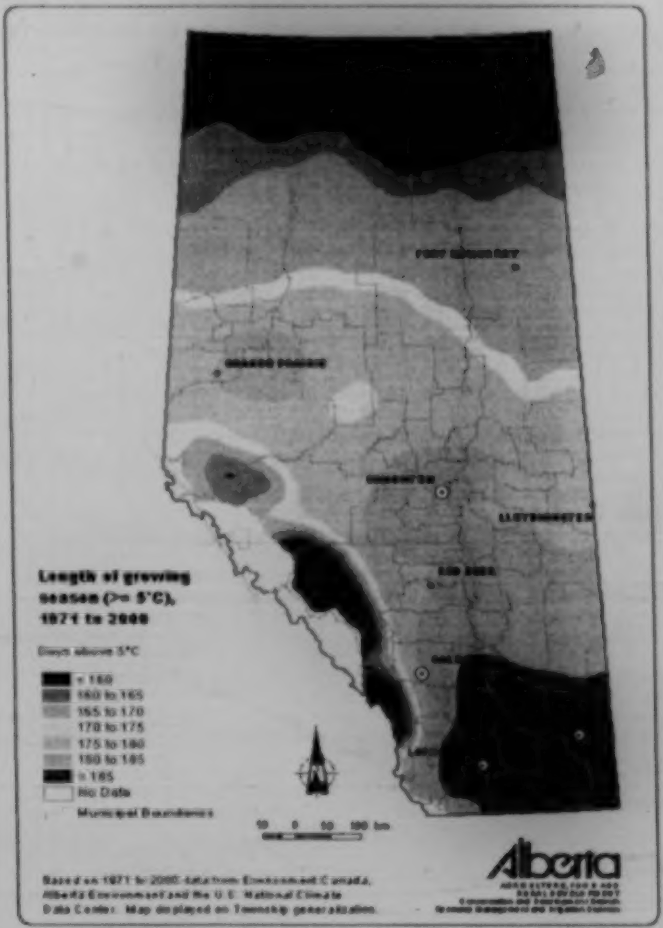
[9] The choice of length of growing season was made based on expert opinion (E. Smith, AAFC). In this part of Alberta, harvesting of grains and oilseeds can occur anytime from August to October depending on the weather. Furthermore, forages and pasture continue to grow well into October and November, again depending on the weather.

Lethbridge has historically had a growing season greater than 185 days, or 6 months. Fifty one years of daily weather data, from 1957 to 2007, were obtained from the Lethbridge Weather station north of Lethbridge. This was the nearest available station that generated complete data for the region; it is located thirty miles southwest of the representative farm on the Little Bow River.

Figure 5.1 - Growing season length in Alberta


Length of growing season (>= 5°C), 1971 to 2000
Days above 5°C
< 160
160 to 165
165 to 170
170 to 175
175 to 180
180 to 185
> 185
No Data
Municipal Boundaries
50 0 50 100 km
Alberta
Based on 1971 to 2000 data from Environment Canada, Alberta Environment and the U.S. National Climate Data Center. Map displayed on Township generalization.

Source: AARD (2008-c)

As stated in Chapter 3, growing degree days (GDD) is a value to represent the accumulation of heat over a growing season. Plants need heat to move throughout their stages of development and while this requirement remains relatively constant from year to year, weather patterns can vary significantly. Because of this, GDD is very useful in predicting variability in crop development. GDD is calculated using the following equation (Corbally and Dang, 2002; Cortus, 2005):

$$Max\left\{\left[\frac{(MaxTemp + MinTemp)}{2}\right] - K, 0\right\}, \qquad (5.1)$$

where $MaxTemp$ is the maximum daily temperature, $MinTemp$ is the minimum temperature and K is a threshold temperature. The threshold temperature is the temperature at which a plant would start to grow. While this temperature is not exactly the same for all crops, five degrees celsius is the generally accepted requirement for plant growth.

One minor limiting factor with this approach is that it does not consider the timing of GDD and GS within the growing season. Since most of the crop growth occurs in the spring and early summer, adequate GS and GDD is more important in these times than during late summer before harvest. A dry and hot spring and early summer may have very damaging effects on crop yields that late season precipitation and ideal growing temperatures cannot repair. A simplifying assumption was made that the distribution of GDD and GS through the growing season was consistent from year to year.

A negative correlation was hypothesized to exist between growing degree days and growing season precipitation. If a growing season has higher values for growing degree days, which implicates more heat, then growing season precipitation should be lower and vice versa. Historically, this was the case for the Lethbridge weather data. The correlation value between growing degree days and growing season precipitation was -0.40 and this inverse relationship was incorporated into the modelling framework.

5.2.1.2 Weather Distributions

Probability distributions of GS and GDD were required in order to properly incorporate weather into the simulation as a stochastic variable. To do this, a specific type of distribution had to be defined that best represented the range of historical weather data. These distributions representing the range of data values were generated within @risk which analyzed the historical data and used best-fit statistical formulas to determine the distributions that would best represent that data.

Table 5.6 shows three test statistics that @risk used to determine the best distribution. These statistics included the Chi-Squared statistic, Anderson-Darling statistic and Kolmogorov-Smirnov statistic. These three tests are used to test whether a data set comes from a population with a specific distribution and whether they work well with continuous distributions (Croarkin and Tobias, 2006). Each test has its statistical strengths and weaknesses but applying and comparing all three tests simultaneously presents a comprehensive assessment of the appropriate distributions (Palisade Corp., 2007). A complete description of these test can be found in appendix E. In short, for each test, the null hypothesis is that the dataset follows a specified distribution and this is rejected if the test statistics for each test is greater than the critical value at the chosen significance level.

Table 5.6 lists the ranking of the top three distributions to use suggested by each test based upon the "fit" statistic which are in parentheses. The fit statistic is a measure of how well a certain distribution fits the historical input data by measuring the deviation of the fitted distribution from the input data. The closer the fit statistics are to zero, the more confidence can be placed in presuming that the distribution is representative and fits the historical data (Palisade Corp., 2007). For GDD, two of the three tests concluded that a logistic distribution was best for the growing season precipitation data. This distribution was subsequently used to represent GS in the Monte Carlo simulation. A logistic distribution has a similar shape to the normal distribution with "fatter" tails (higher kurtosis) (Balakrishnan, 1992).

Table 5.6 - Test statistics for distribution fitting

Variable	**Statistical Test**		
GDD	**Chi-Squared**	**Anderson-Darling**	**Kolmogorov-Smirnov**
	Logistic (2.48)	Log Logistic (0.2929)	Logistic (0.0611)
	Log Logistic (3.12)	Logistic (0.2584)	Log Logistic (0.0659)
	Lognormal (6.00)	Lognormal (0.3233)	Lognormal (0.0763)
GS			
	Logistic (5.68)	LogLogistic (0.2368)	LogLogistic (0.0682)
	Normal (6.00)	Lognormal (0.3011)	Lognormal (0.0711)
	Triangle (7.92)	Triangle (1.1857)	Triangle (0.1558)

Note: GS stands for Growing Season Precipitation, GDD stands for growing degree days

Deciding on a correct distribution for growing season precipitation (GS) was more challenging. As shown in Table 5.6, the loglogistic was deemed to be best fit by @risk for two of the three tests. However, even though there may be more than one best-fit distribution available, there is no rule as to which distribution will give you the "best" outcome in a specific simulation model (Palisade Corp., 2007). The user or model developer must decide what distribution is best to use in context with the model being developed and the problem trying to be solved. In this study, the dataset incorporated 50 years worth of daily data which included both extremes in GS values, that is, very high levels of growing season precipitation, and very low levels. When simulations were run with the distributions deemed "best fit" by @risk (logistic and loglogistic distributions), the tails that are representative of these distributions gave weather events in terms of GS that were well outside of the extremes of values that were found in the last 50 years. The extreme weather values that arose from these tails led to unrealistic outputs in other aspects of the model. As a result, the distribution that was subsequently chosen to be used for the GS distribution which fit the data reasonably well was the triangle distribution even though @risk did not choose it to be best fit (Table 5.6)[10]. The triangle distribution is a continuous probability distribution similar to the normal distribution. However, a triangle distribution has an upper and lower limit rather than a tails extending to infinity. The existence of these limits held GS within reasonable limits for the area and therefore was chosen for the model.

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[10] Graphs of the distributions chosen and best fits for GS and GDD are shown in appendix F.

5.2.2 Crop and Forage Yield Models

As discussed earlier, weather was used as the main variable in determining crop and forage yields from year to year. Yields were regressed as a function of GS and GDD. The source of the weather data required to calculate these two explanatory variables was discussed in the previous section. Historical crop yields were obtained from Alberta Agriculture and Rural Development for Agricultural Census Region 2. Crop yields for barley, canola, durum wheat and spring wheat were available from 1956. However, wheat was aggregated into "All Wheat" from 1956 to 1981, then durum was provided separately starting in 1982.

5.2.2.1 Crop Yield Model Estimation and Incorporation

Based on the information given above, crop yield estimation and thus the introduction of risk into the simulation from crop yield variability is due to the variability in GS and GDD. The basis for crop yield estimation comes from the water supply-water demand ratio in the form of quadratic equations along with a random error component independent of weather. The assumption is made that crop inputs (fertilizer, chemical, etc.) do not change over time and thus do not impact yields from year to year. The equations estimated for crop yields are provided below.

$$\begin{aligned}
y_t^C &= \alpha_0^C + \alpha_1^C \frac{GS}{GDD} + \alpha_2^C \left(\frac{GS}{GDD}\right)^2 + \varepsilon_t^C \\
y_t^B &= \alpha_0^B + \alpha_1^B \frac{GS}{GDD} + \alpha_2^B \left(\frac{GS}{GDD}\right)^2 + \varepsilon_t^B \\
y_t^D &= \alpha_0^D + \alpha_1^D \frac{GS}{GDD} + \alpha_2^D \left(\frac{GS}{GDD}\right)^2 + \varepsilon_t^D \\
y_t^W &= \alpha_0^W + \alpha_1^W \frac{GS}{GDD} + \alpha_2^W \left(\frac{GS}{GDD}\right)^2 + \varepsilon_t^W ,
\end{aligned} \tag{5.2}$$

where y_t^C, y_t^B, y_t^D and y_t^W represent crop yields for canola, barley, durum wheat and spring wheat in tonnes per acre respectively. The $\alpha's$ are the model parameters, where α_0 represents the "intercept", α_1 represents the coefficient on the linear term, and α_2 represents the coefficient on the quadratic term; ε_t is the error term.

Water supply is represented by the amount of precipitation over the growing season. This comes from the GS dataset. Water demand is affected by growing degree days; the warmer a season is in terms of GDD, the greater the need for precipitation. The linear ratio allows for the analysis to incorporate the impact of increased precipitation relative to growing degree days (Cortus, 2005). The quadratic term allows for the modelling of extreme events where a crop receives too much or not enough moisture or heat in a growing season. In these situations, "extreme" values of GS or GDD would potentially have damaging effects on crop yields.

Thus the coefficients (α) are hypothesized to be negative.

Seemingly unrelated regression (SUR) was used in crop yield estimation. SUR is an econometric estimation that recognizes the existence of contemporaneous correlation (Judge et al., 1988). Contemporaneous correlation is used to describe the correlation of errors between equations. Rather than estimate crop yield equations separately using ordinary least squares estimation, it is done as a system and provides for a more efficient estimation (Judge et al., 1998). The yields of different crops are likely to be correlated over time and SUR allows for the estimation of these correlations that are needed to run the representative simulation. The correlations between crop yields were calculated using the variance-covariance matrix from SUR estimation. The use of SUR was further justified through the results of Breusch-Pagan and likelihood ratio tests which reported test statistics of 76.82 and 76.34 respectively. The associated p-values were less than 0.0001. Table 5.7 shows the parameters and statistics for the estimated crop yield equations. Durum wheat and barley were the most responsive to changes in the linear and quadratic water use-water demand ratio with canola being the least responsive. The hypothesis of negative quadratic coefficients was borne out in the resulting parameter estimates, showing that extreme weather events have a negative impact on all crop yields.

Table 5.7 - Crop yield model estimation equations

Variable	Estimated Coefficients			
	Durum Wheat	Spring Wheat	Barley	Canola
(GS/GDD)	7.672***	5.797**	6.540***	2.1479
	(2.558)	(2.106)	(2.023)	(1.521)
$(GS/GDD)^2$	-13.775***	-9.467*	-12.848**	-2.7241
	(6.049)	(4.981)	(4.784)	(3.597)
Constant	0.1544	0.4757**	0.7432***	0.4404**
Std. Error	0.1815	0.1495	0.1436	0.1079
R^2	0.5004	0.5450	0.4425	0.3808

*** = significance at 1% ** = significance at 5% * = significance at 10%

Crop yield calculations for a particular year are made based on draws from three separate distributions. The first two draws for GS and GDD, explained previously. These were drawn from their respective distributions and combined to form the water supply-water demand ratio. The ratio was then substituted into the yield equation specified previously. The third draw is a crop error draw taken from a standard normal distribution; N(0,1).

Due to the assumption that crop yields are correlated with each other, the error terms of crop yields (ε) had to be adjusted according to these correlations and then scaled by their respective standard deviations (Cortus, 2005). Once crop yield errors were adjusted, they were substituted back into their respective yield equations. Following Hull (1997) and Cortus (2005), error correlations between all crops were calculated using the following formulae:

$$\varepsilon_m = \sum_{k=1}^{k=m} \delta_{mk} x_k \quad \textit{subject to:}$$

$$\sum_k \delta_{mk}^2 = 1$$

$$\sum_k \delta_{mk}\delta_{jk} = \rho_{m,j}, \tag{5.3}$$

where the corrected error for crop *m* was ε_m. For example, the corrected error for durum wheat, ε_t^D in equation 5.2, is equivalent to ε_D shown below. In equation 5.3, x_k is the initial standard error normal draw for crop *k*. For crops other than durum, the error is "corrected" or adjusted using the crop error correlations; $\rho_{m,j}$ is the correlation between errors for crops *m* and *j* and δ_{mk} were the terms estimated in the constraints above. Solving for the δ_{mk} terms produced the following equations for the adjusted or corrected error terms:

$$\varepsilon_D = x_D \qquad (5.4)$$

$$\varepsilon_W = \rho_{D.W} x_D + \left(\sqrt{1-\rho_{D.W}^2}\right) x_W \qquad (5.5)$$

$$\varepsilon_B = \rho_{D.B} x_D + \left(\frac{\rho_{W.B} - \rho_{D.W}\rho_{D.B}}{\sqrt{1-\rho_{D.W}^2}}\right) x_W + \left[\sqrt{1-\rho_{D.B}^2 - \left(\frac{\rho_{W.B} - \rho_{D.W}\rho_{D.B}}{\sqrt{1-\rho_{D.W}^2}}\right)^2}\,\right] x_B \qquad (5.6)$$

$$\varepsilon_C = \rho_{D,C} x_D + \left(\frac{\rho_{W.C} - \rho_{D.W}\rho_{D,C}}{\sqrt{1-\rho_{D.W}^2}}\right) x_W + \left[\frac{\rho_{B,C} - \rho_{D.B}\rho_{D,C} - \left(\frac{\rho_{W.B} - \rho_{D.W}\rho_{D.B}}{\sqrt{1-\rho_{D.W}^2}}\right)\left(\frac{\rho_{W.C} - \rho_{D.W}\rho_{D.C}}{\sqrt{1-\rho_{D.W}^2}}\right)}{\sqrt{1-\rho_{D.B}^2 - \left(\frac{\rho_{W.B} - \rho_{D.W}\rho_{D.B}}{\sqrt{1-\rho_{D.W}^2}}\right)^2}}\right] x_B$$

$$+\left\{\sqrt{1-\rho_{D.C}^2 - \left(\frac{\rho_{W.C} - \rho_{D.W}\rho_{D.C}}{\sqrt{1-\rho_{D.W}^2}}\right)^2 - \left[\frac{\rho_{B,C} - \rho_{D.B}\rho_{D.C} - \left(\frac{\rho_{W.B} - \rho_{D.W}\rho_{D.B}}{\sqrt{1-\rho_{D.W}^2}}\right)\left(\frac{\rho_{W.C} - \rho_{D.W}\rho_{D.C}}{\sqrt{1-\rho_{D.W}^2}}\right)}{\sqrt{1-\rho_{D.B}^2 - \left(\frac{\rho_{W.B} - \rho_{D.W}\rho_{D.B}}{\sqrt{1-\rho_{D.W}^2}}\right)^2}}\right]^2}\,\right\} x_C$$

$$(5.7)$$

The error correlations from the SUR crop yield equation estimates are shown in Table 5.8.

Table 5.8 - Estimated crop yield estimation equation error correlations (ε)

	ε_t^D	ε_t^W	ε_t^B	ε_t^c
ε_t^D	1			
ε_t^W	0.5854	1		
ε_t^B	0.7315	0.5955	1	
ε_t^c	0.6634	0.4349	0.7187	1

5.2.2.2 Crop Yield Verification

The above econometric results were tested in simulation to determine how representative the resulting yields were with respect to reality. Any deviations or illogical results were corrected. Simulations on occasion produced negative crop yields; this was fixed by setting a minimum yield of zero tonnes/acre.

The crop yield equations in Table 5.7 produced mean values for annual crop yields that were above the historical averages. This was corrected by adjusting the constant downward until a simulated mean crop yield equalled the historical average. Table 5.9 provides the historical crop yield mean, unadjusted simulated crop yield mean and simulated crop yield mean once adjusted with new constant values.

Table 5.9 - Comparison of actual and modelled crop yields (tonnes/acre)

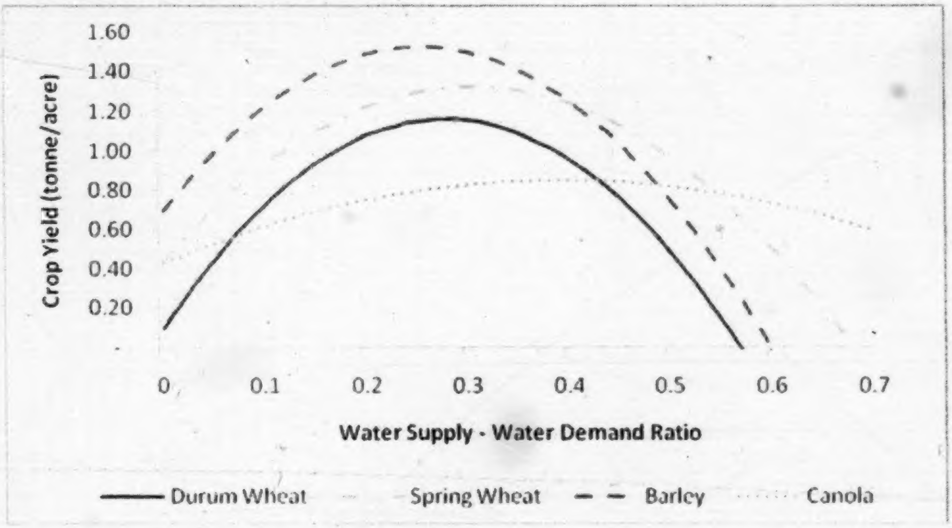
	Historical Mean	Pre-Adjustment Simulated Mean Yield	Post-Adjustment Simulated Mean Yield	Adjusted Constant
Durum Wheat	0.97	1.03	0.97	0.0955
Spring Wheat	1.12	1.16	1.12	0.4400
Barley	1.40	1.46	1.40	0.6900
Canola	0.70	0.71	0.70	0.4300

Figure 5.2 shows the range of crop yields with varying water supply-water demand ratio values after the adjustment for the constant. This figure is representative of crop responses to simulated weather. As noted earlier, durum wheat, spring wheat and barley are most sensitive to excessive moisture (Rigaux and Singh, 1997). Figure 5.2

shows the negative impacts of extreme weather events as crop yields decrease for both low and high water use-water demand ratios.

To accompany the adjustment in the constant, a further adjustment was made to standard errors. Aggregation bias may be a problem when using regional crop yield observations as representative crop yields for an individual farm (Rudstrom et al., 2002). The variability in crop yields is greater at the individual farm or field level when compared to crop yield variability at the regional level (Marra and Schurle, 1994). Popp et al. (2005) discussed how much aggregation distortion could be expected between specific field crop yields and an average of crop yields of an aggregation of fields in Manitoba. They concluded that the use of aggregate data (averaging individual field data) greatly under-estimated field-level crop yield risk in most situations. For wheat, individual field variance could be as much as eleven times greater than the aggregate crop yield variance. This is a problem in many crop yield studies as it is difficult to get accurate, consistent and complete data for individual field yields. Most crop yield data are available only at an aggregated level representative of county or municipality averages.

Figure 5.2 - Graph of yield equations



In Kentucky, individual wheat field yield variability was determined to be 2.71 time higher than for county level data (Debrah and Hall, 1989). Marra and Schurle (1994) provided a solution to the problem of possible underestimation of crop yield variances. They estimated the differences between field and regional crop level variances for wheat in Kansas. From this, an adjustment factor was determined to account for the possibility that regional crop yield variability would underestimate farm level variance. For every 1% difference between regional acreage and farm acreage of wheat, the standard deviation of wheat yield was increased by 0.1%. This adjustment has been referenced in other studies and was deemed to be a useful approach for this study.

Cortus (2005) simulated crop yields similar to this study and adjusted field level standard deviations using an ad-hoc adjustment. Standard deviations were adjusted until simulations attained maximum and minimum yield values that were found in the historical field data. Cortus then compared the ad-hoc adjustment to the Marra-Schurle factor and the comparison showed that both processes adjusted crop yields similarly[11].

In this study, initial crop yield simulations already reached maximum and minimum values so no ad-hoc adjustment was performed on standard deviations. However, the Marra-Schurle factor was still imposed as the historical yields used in the equation estimation averages were regional averages and not farm specific values. Table 5.10 compares the original standard errors to the new, Marra-Schurle factor adjusted standard errors and shows the percentage difference between the two values for each crop. Standard deviations nearly doubled in most cases which is below what Popp et al. (2005) and Debrah and Hall (1989) deemed as the maximum increases in field crop yield standard deviations from regional crop yield standard deviations. Table 5.11 shows the resulting confidence interval comparisons between simulation and historical data after all adjustments. It shows that the adjustments have added variability to the field level crop yields as 90% upper and lower confidence intervals from simulation exceed that of actual historical data.

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[11] Cortus comparison is shown in appendix G.

Table 5.10 - Standard deviation adjustments

	Original St. Dev.	Marra-Schurle Factor Adjusted St. Dev.	% Difference
Durum Wheat	0.1815	0.3305	82.1%
Spring Wheat	0.1494	0.2899	94.0%
Barley	0.1435	0.2404	67.5%
Canola	0.1079	0.2119	96.4%

Table 5.11 - Comparison of means and 90% confidence intervals between simulation and historical data for agricultural census division #2 (CD 2)

	Crop Yield (tonne/acre)							
	Durum Wheat		Spring Wheat		Barley		Canola	
	Simulation	CD 2	Simulation	CD 2	Simulation	CD 2	Simulation	CD 2
Upper Bound of CI	1.48	1.33	1.61	1.46	1.80	1.64	1.24	0.90
Mean	0.97	0.97	1.12	1.12	1.40	1.40	0.71	0.71
Lower Bound of CI	0.39	0.50	0.63	0.78	0.98	1.08	0.12	0.44

5.2.3 Forage Yield Model Estimation & Incorporation

Had the same type of forage and silage yield data been available for the geographical area, a similar modelling procedure to that used for cereal/oilseed crops would have been used to estimate forage yields. However, these data were not available. As a result, an alternative approach was required.

It was decided to use the covariability between annual forage yields and annual crop yields to calculate forage yields. Alberta Agriculture and Rural Development provided a comprehensive yield correlation matrix for major crop and forage types for agricultural regions in Alberta. As well, they provided yields for greenfeed, barley silage and alfalfa-grass hay (Kaliel 2007) that could be considered as "representative" for farms in the area in which the representative farm is located.

Forage yields for each year and iteration in the simulation model were calculated using the yield correlations between the alternative forage types (i.e., greenfeed, barley silage and alfalfa-grass hay) and barley grain. The stochastic variability of barley provided a proxy to calculate stochastic forage yields. Barley was chosen because both greenfeed and silage were made using barley. The yield correlations for barley, barley silage and alfalfa grass hay are provided in Table 5.12.

Greenfeed for the farm is composed of a barley cover crop. Silage production on the farm also utilizes barley. In the case of each of these crops, the forage yield was calculated by adjusting the simulated annual barley yield using the correlation coefficients shown in Table 5.12[12]. For every 1% change in the annual barley yield, there is a 0.725% change in barley silage and greenfeed yield. The starting values for forage yields were assumed to be the mean yield over the last two years for the area, as provided by Alberta Agriculture and Rural Development (Kaliel, 2007).

This approach was repeated for alfalfa-grass hay. For every 1% change in barley yield, alfalfa-grass hay was adjusted by 0.3%. In Section 5.1.1.1.1 the pattern of forage yields over the stand length was discussed, with yields initially increasing and then decreasing again. Therefore, after accounting for yield fluctuations through the correlation with the annual barley yield, alfalfa-grass hay yields were adjusted again depending on the year of the stand using Table 5.3. For example, an initial hay yield in year three of its stand life was derived from its correlation to the annual barley yield simulated by the model in that same year using the mean yield obtained from Alberta Agriculture and Food, which is then used as a mean stand yield. That hay yield would then be adjusted up by 20.38% (Table 5.3) to estimate the final hay yield in that growing season.

Table 5.12 - Crop, forage and pasture yield correlation matrix

	Greenfeed	**Barley Silage**	**Alf/Grs Hay**	**Tame Pasture**
Barley	0.725	0.725	0.3	
Native Pasture				0.6

Source: Kaliel (2007)

5.2.4 Grazing Pasture Yield Models

In addition to annual crop and forage yields, a relationship for pasture yield response as a function of weather was required. A major factor determining the success of the cow/calf enterprise is grazing season length. Stocking rates on pasture are primarily determined by pasture forage availability which is influenced by growing conditions (Bork et al., 2001). A longer grazing season allows cows and calves to graze longer, thereby increasing calf weights and decreasing winter feeding time. Increased calf weights lead to higher calf revenues and decreased winter feeding time (i.e., lower winter feed cost).

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[12] Refer to sections 5.1.1.1.1 and 5.1.1.1.2 for an explanation of greenfeed and silage composition.

5.2.4.1 Pasture Yield Estimation

A number of different options were available for native pasture yield functions. Miller (2002) used a linear yield function estimated by Sneva and Hyder (1962). Their function used a precipitation index as the independent variable to analyze different grazing management strategies. Similarly, Bork et al. (2001) analyzed the herbage response of boreal grasslands in Alberta to precipitation. Bork et al. (2001) produced a number of pasture forage yield equations which were dependent upon precipitation over the growing season. These equations were both linear and quadratic and it was concluded that pasture yield responses were very site specific and that yield equations estimated for one geographical area with a specific soil type should not be applied to other geographical and/or soil areas.

Smoliak (1986) estimated range forage yields on native range in Manyberries, Alberta. This area is located approximately 150 kilometres southeast of the representative farm in the brown to dark brown soil zone. Smoliak also estimated a number of linear yield equations dependent upon monthly temperature and precipitation values.

The dataset used for the Manyberries analysis was determined to be adequate to estimate a native pasture yield equation for the representative farm. In particular, the forage species found in the two areas were very similar. The species found on land used in the Smoliak study (in order of decreasing yield) included needle-and-thread, western wheatgrass, bluegrama, junegrass, and leaf sedge. The forages found on native pasture at the representative farm were blue grama, needle-and-thread, western and crested wheatgrass and june grass. The only vegetation type missing was leaf sedge which was lowest yielding vegetation type in Manyberries. The only drawback of using Smoliak's data was that the Manyberries data set only went to 1983.

Pasture forage yield (kg per acre) for Manyberries from 1957 to 1983 was regressed on growing season precipitation (GS) in millimetres to estimate a linear native pasture yield equation. The estimated parameters for this equation are provided in Table 5.13.

Table 5.13 - Native pasture yield model equation

Variable	Pasture Yield
(GS)	0.61135*** *0.1409*
Constant	55.272**
Std. Error	49.115
R^2	0.4295

*** = significance at 1% ** = significance at 5% * = significance at 10%

5.2.4.2 Pasture Yield Incorporation

The estimated native pasture forage yield equation provided yield values in kgs/acre. However, the units required for the purposes of pasture productivity in the simulation analysis were animal unit months (AUM) (Table 5.1). Therefore, a conversion was required to compare the equation estimates to the estimated pasture forage yield in AUMs given by Alberta Agriculture and Rural Development for the Lower Little Bow.

An AUM is directly tied to the amount of forage that is needed by a cow and her suckling calf and the productivity of the pasture. The initial AUM values given in Table 5.1 were the starting point in determining pasture productivity. The total amount of pasture production is actually greater than the given values due to the wastage of forage due to various factors. The following discussion describes how the initial AUM value was converted to a representative pasture production value in kgs/acre for native pasture.

First, AUM's were converted into carrying capacity (AUM/month) by multiplying AUM values by the acreage of the pasture (Table 5.1). This gave the total carrying capacity for one month. This carrying capacity was then multiplied by the monthly consumption of an animal unit[13]. This resulting value represented the total utilizable forage over the grazing season. However, this is not yet representative of the total forage produced by the pasture. Much of the forage is subject to trampling and destruction by animals and thus not available for grazing. This is taken into account through a pasture utilization rate. The pasture utilization rate is set at 50% in this study. This value is commonly used in pasture analysis (NDSU, 2006). Hence, the previously calculated total utilizable forage is increased by 50%.

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[13] See section 5.1.2.1 for a description of the monthly pasture consumption per animal.

This value is then adjusted again by the proper grazing factor to get the total pasture forage production. The proper grazing factor accounts for the fact that livestock may not utilize the entire land area. Livestock tend to stay near water sources when on pasture (Miner et al. (1992), Smith et al. (1992), Clawson (1993), Godwin and Miner (1996)). This leaves a large amount of pasture that would be underutilized or wasted over a grazing season. The initial proper grazing factor used here was also 50% (NDSU, 2006). These adjustments resulted in a value for the total pasture forage productivity over the grazing season and this value is representative of the initial AUM value.

A sample calculation for pasture utilization and production is provided below. For purposes of this example, assume that the AUM value for a given pasture is 1 AUM/acre over the grazing season, the pasture size is one thousand acres, the monthly consumption of animals is 1000 pounds/AU and the pasture utilization rate and proper grazing factor is set at 50%. The total forage yield over the grazing season is calculated using the following steps:

- total pasture carrying capacity calculated as AUMs/acre multiplied by the number of acres (i.e., 1 AUM/acre * 1000 acres) and is equal to 1000 AUM
- total utilized forage is calculated as total carrying capacity multiplied by the monthly consumption per AU (i.e., 1000 AUM * 1000 AU) and is equal to 1,000,000 pounds
- total available forage is calculated as total utilized forage divided by the utilization factor (i.e., 1,000,000 pounds / 0.5) and is equal to 2,000,000 pounds
- total forage production is calculated as total available forage divided by the grazing factor (i.e., 2,000,000 pounds / 0.5) and is equal to 4,000,000
- total production is converted to a per acre yield through dividing by the total number of acres (i.e., 4,000,000 pounds / 1000 acres) and is equal to 4000 pounds per acre or 1815 kg per acre

In this way, pasture requirements and pasture production are linked.

After the pasture forage yield was calculated from given AUM values, it was used as the mean forage yield value over the simulation. Yield estimates based on Manyberries data underestimated the pasture forage yield value that was calculated using simple ordinary least squares (Table 5.13). The constant for the estimated yield equation in Table 5.13 was adjusted upward until the estimated mean pasture forage yield matched the calculated pasture forage yield from the given AUM values.

Through the stochastic process, any deviation from the mean forage yield had to be converted back into an AUM value. As described in section 5.1.2.1, one AUM/acre is equivalent to 799 pounds (362 kgs) of forage. Thus, for every 1% (3.62kg) change in pasture forage yield per acre, AUMs/acre would change by 1% (0.01 AUM) in the same direction.

Tame pasture is also a part of the total pasture base, making up 14% of the total base. The difference between tame and native pasture is the readiness of grazing. Tame pasture will include grasses seeded in previous years that are higher yielding and can be grazed at earlier times in the season compared to native pasture (Frank et al., 1993). The initial tame pasture forage yield value was calculated using the same process described above for native pasture. A correlation value was then used to measure the change in tame pasture forage yield productivity over time with respect to native forage yield as there was no way of econometrically estimating tame pasture forage yield. Table 5.12 shows the correlation between tame and native pasture. For every 1% change in native pasture forage yield, tame pasture yield would change by 0.6%.

5.2.5 Crop and Forage Price Models

5.2.5.1 Crop Price Estimation

As with crop, forage and pasture yields, commodity prices followed a stochastic process within the simulation model and equations were estimated for crops and forage prices. Annual barley and canola prices were obtained from Alberta Agriculture and Food (Kaliel, 2007). Annual durum and hard red spring wheat prices were obtained from the

Canadian Wheat Board[14]. Crop price data were adjusted for inflation before undertaking any econometric analysis. This was done using the Consumer Price Index for All Products (CPI) from the Statistics Canada CANSIM database.

The data was tested for stationarity using Dickey-Fuller tests. A stationary process is a stochastic process whereby a data series probability distribution of outcomes is the same for all time periods. In other words, the mean and variance of the distribution does not change over time within a stationary dataset (Dixit and Pyndyk, 1994). Two versions of the test were done on the data; one assuming no trend in prices over time and one assuming that prices do exhibit a trend.

Table 5.14 shows test statistics and 10% critical values for the Dickey-Fuller tests. The null hypothesis is that the data are non-stationary and this can be rejected if the t-stat is smaller than the critical value. This null hypothesis was rejected for barley prices, with and without trends. The null hypothesis was also rejected for spring wheat when stationarity was tested with a trend.

Table 5.14 - Dickey-Fuller test results

Crop	Without Trend	With Trend
Spring Wheat	-1.66	-3.20
Durum Wheat	-1.90	-2.88
Barley	-3.93	-3.74
Canola	-2.39	-2.71
Critical Value (10%)	**-2.57**	**-3.13**

Even though non-stationarity was not rejected in some cases, this result was ignored and the price equations were estimated under the assumption of stationarity. This was done for a number of reasons. Cortus (2005) found non-stationarity in historical crop price data sets and estimated a non-stationary price model. Problems with this came in the form of unrealistic resulting price distributions with prices ranging from $1/tonne to $20,000/tonne. As a result Cortus used stationary commodity price models. Dixit and Pindyck (1994) argue that it is difficult to distinguish between stationary and non-stationary processes with small, annual data sets of approximately 30 years. This study uses 34 years of annual historical price data and Cortus (2005) had 43 years of historical data. Furthermore, the Dickey-Fuller test is known to be of low power in the testing of unit roots and stationarity (Verbeek, 2004). Simply because the existence of unit roots was not rejected, it does not mean that it is necessarily always correct (Cortus, 2005). It just may be the case that there is insufficient evidence in the small data set to reject it (Verbeek, 2004). The fact that the price series demonstrated both stationarity and non-stationarity raises questions as to whether it can be assumed that the price data series is non-stationary.

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[14] Durum and spring wheat prices from the Canadian Wheat Board were assumed to be of Grade 1with a protein content of 13.5%.

Similar to yield estimation, price equations were estimated using SUR to account for possible correlation between historical crop prices. The historical prices series was used to forecast prices for the farm. The Akaike Information Criterion (AIC) and Schwartz Information Criterion (SIC) were used to determine the number of lags appropriate for crop price estimation for each crop. Ordinary least squares estimates with lagged prices from one to five periods were tested and the AIC and SIC outputs are shown in Table 5.15. The optimal lag is represented by the lowest AIC and/or SIC value for each crop. The most appropriate lag length was four for all crops except durum wheat. The optimal lag length for durum was found to be three years.

Table 5.15 - AIC and SIC values for crop price equations

Lag	Spring Wheat		Durum Wheat		Barley		Canola	
	AIC	SIC	AIC	SIC	AIC	SIC	AIC	SIC
1	8.7599	8.8506	9.5647	9.6554	7.3301	7.4208	9.2755	9.3662
2	7.6512	7.7886	7.9027	8.0401	7.4139	7.5512	8.9584	9.0958
3	7.6227	7.8078	7.8118	7.9969	7.2015	7.3865	8.6621	8.8471
4	7.4576	7.6912	7.8448	8.0784	7.1351	7.3686	8.3657	8.5992
5	7.5201	7.8030	7.8358	8.1187	7.1776	7.4605	8.4688	8.7517

The price model was then estimated as follows:

$$\begin{aligned}
P_t^C &= \beta_0 + \beta_1 P_{t-1}^C + \beta_2 P_{t-2}^C + \beta_3 P_{t-3}^C + \beta_4 P_{t-4}^C + \varepsilon_t^C \\
P_t^W &= \beta_0 + \beta_1 P_{t-1}^W + \beta_2 P_{t-2}^W + \beta_3 P_{t-3}^W + \beta_4 P_{t-4}^W + \varepsilon_t^W \\
P_t^D &= \beta_0 + \beta_1 P_{t-1}^D + \beta_2 P_{t-2}^D + \beta_3 P_{t-3}^D + \varepsilon_t^D \\
P_t^B &= \beta_0 + \beta_1 P_{t-1}^B + \beta_2 P_{t-2}^B + \beta_3 P_{t-3}^B + \beta_4 P_{t-4}^B + \varepsilon_t^B
\end{aligned} \tag{5.8}$$

where P^C, P^W, P^D and P^B are the prices for canola, spring wheat, durum wheat and barley, respectively, P_{t-n} is the price lagged n periods from the current period (t) and ε_t is the error term.

5.2.5.2 Crop Price Incorporation and Verification

The parameter estimates for the crop price equations are shown in Table 5.16. Almost all of the coefficients are statistically significant and R^2 values range from 0.76 to 0.89 over the crop types. As noted above, the equations were estimated using SUR. Breusch-Pagan and likelihood ratio test reported test statistics of 23.84 and 29.70 respectively which gave p-values less than 0.001.Similar to the situation for crop yields, it was assumed that that crop prices are correlated over time. Using SUR allowed the correlation between the crop prices to be calculated and these correlations were incorporated into the process used to calculate the stochastic prices in the simulation model. This was done in the same fashion as for the crop yields, as explained in section 5.2.2.1. Errors initially drawn from a normal distribution were adjusted using error correlation values estimated using equations 5.3 to 5.7. Due to the fact that crop prices were functions of lagged prices, initial prices at P_{t-1} to P_{t-4} had to be specified in order to set the first simulated data point where t=0. The historical average price (calculated from the same time series used to estimate the price equations) was used as the starting value for each of the lagged prices (Cortus, 2005).

Table 5.17 presents the price error correlation matrix used to adjust the stochastic errors used in calculating annual crop prices in the simulation model. Spring wheat and durum have the highest correlation value. Given the similarity of the crop genetics between the two crops (i.e., they are both types of wheat), this is not surprising.

Table 5.16 - Estimated crop price equations

Variable	Estimated Coefficients			
	Canola	**Spring Wheat**	**Durum Wheat**	**Barley**
1 Lag	0.8257***	1.0339***	0.9788***	0.8271***
	0.1299	*0.1446*	*0.1455*	*0.1457*
2 Lags	-0.4001***	-0.5277**	-.04749**	0.4716***
	0.1427	*0.2062*	*0.1884*	*0.1796*
3 Lags	0.0096	0.1394	0.1995*	0.1473
	0.1026	*0.1534*	*0.1078*	*0.1820*
4 Lags	0.2111**	0.1573**		0.1923***
	0.0865	*0.0776*		*0.1163*
Constant	95.6010***	44.138**	82.247***	40.536***
Std Error	56.2510	35.818	45.052	30.257
R^2	0.8897	0.8395	0.7528	0.7550

*** = significance a 1% ** = significance at 5% * = significance at 10%

Table 5.17 - Estimated crop price equation error correlations (ε)

	ε_t^D	ε_t^W	ε_t^B	ε_t^c
ε_t^D	1			
ε_t^W	0.6363	1		
ε_t^B	0.4549	0.1859	1	
ε_t^c	0.3729	0.2857	0.5023	1

Given the assumptions regarding crop prices (i.e., stationarity), stochastic prices drawn in the simulation analysis trended towards a long run mean. The mean from the simulation results was compared to the historical, inflation adjusted mean, calculated using the original crop price data. These two values, for each crop, are shown in Table 5.18. Trial simulations were performed to test the range of prices that were generated over time to ensure that simulated prices were reasonable. This was also done to test if the assumption of stationarity was reasonable. From a comparison of values in Table 5.18, the assumption appears to be justified, given the small differences between simulated average and historical average prices. Some of the price difference between the historical and simulated mean can be explained by the fact that the econometric model does not explain all the variability in prices (i.e., R^2 values in Table 5.16 are “significant” but less than one).

Table 5.18 - Comparison of 10 year historical price data and @risk simulated value for crop prices in year 20 ($/tonne)

	Canola	Spring Wheat	Durum Wheat	Barley
Historical Mean	354.3	233.9	269.5	130.7
@Risk Simulated Value	351.9	228.3	272.6	132.0

5.2.5.3 Forage Price Estimation and Incorporation

A dataset for historical barley silage and/or hay prices was not available for use in estimating price equations for these commodities. As a result, hay prices in the simulation were assumed not to be stochastic and were set at a market price representative of southern Alberta over the last 2 years (Kaliel, 2007); the price was set at $97.46 per tonne.

A common approach used to value barley silage is to use commercial barley market prices as a proxy. This assumes that the price for barley silage is directly related to the price of barley grain. This approach was used in the current study, and so barley silage price was linked to the stochastic barley price simulated in the model. Assuming a 65% moisture level for barley silage, a multiplier of eight is used to convert the barley grain price (on a $ per bushel basis) to value per tonne of standing silage crop (AARD, 2006-d). Standing crop means that the barley is still on the field and has not been harvested. For example, if commercial barley is valued at $3.5/bushel then barley silage would be priced at $42/tonne. A multiplier of twelve is used for harvested silage (AARD, 2006-d). The multiplier is higher for harvested silage because the buyer does not need to harvest the crop and thus is also paying for "convenience". For the purpose of pricing barley silage in this study, it is assumed that the silage has been harvested and is in storage. Therefore, the barley silage forage price per tonne is calculated as twelve times the stochastic simulation barley grain price.[15]

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[15] The bushel to tonne conversion is provided in appendix H.

5.2.6 Beef Price Models

5.2.6.1 Beef Price Estimation

Stochastic beef prices are calculated and validated using the same process and techniques as for crop prices. Specifically, a system of time series equations is estimated for the various beef prices used in the simulation and correlations between beef price errors in that system are used to adjust the random component in the calculation of the simulated prices . Southern Alberta prices for feeder heifers, feeder steers and cull cows were obtained from Alberta Agriculture and Food (Kaliel, 2007), for the period May 1986 to December 2006. The price series included prices for a range of weight classes; 4 cwt[16] to 5 cwt, 5 cwt to 6 cwt, 6 cwt to 7 cwt and 7 cwt to 8 cwt, for both heifers and steers. The initial prices series used for the price equation estimation was for 5 cwt to 6 cwt calves. This series was chosen because the target calf selling weight of 550 pounds is in this range.

The historical beef prices were adjusted for inflation using the Consumer Price Index of All Products (CPI) from Statistics Canada. Monthly price data were available but it was decided that prices would be drawn twice a year in the simulation analysis. This decision was made based on the implied beef marketing strategy for this farm. It was assumed that market calves and cull cows would potentially be sold in May and November of each year. Thus, the months chosen from the data series to be used in the price equation estimation were November and May prices from 1986 to 2006.

As with the crop prices, Dickey-Fuller tests were performed on the beef price data to check for stationarity. Table 5.19 shows that the null hypothesis of non-stationarity was not rejected for any of the historical prices series, with or without trends; that is, the test statistics were not smaller than the 10% critical values. The data exhibited non-stationarity. However, in estimating the beef price equations, stationarity was assumed for the same reasons as for the crop price estimation (i.e., as discussed in section 5.2.4.1). However, performing the test is still important in order to recognize the possibility of existence of non-stationarity within the prices in the event that there are unexpected results from the econometric estimation.

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[16] Cwt is commonly known as "one hundred weights" in pounds. One cwt is equal to one hundred pounds.

Table 5.19 - Dickey-Fuller test results

	Without Trend	With Trend
Feeder Heifer	-1.72	-1.98
Feeder Steer	-1.77	-2.07
Cull Cows	-1.55	-1.73
Critical Value (10%)	**-2.57**	**-3.13**

Again, seemingly unrelated regression (SUR) was used to estimate beef prices where lag length was determined using AIC and SIC statistics (Table 5.20). The optimal lag length for heifers, steers and cull cows were three, two and three years, respectively. This was determined by choosing the lowest value of AIC and/or SIC for each price series. In one case, feeder heifers, the AIC and SIC statistics provided conflicting results for lag length. For this price series, the lowest AIC value was found at a lag length of three and the lowest SIC value was found at a lag length of two (Table 5.20). However, since the AIC is a better estimator of lag length for shorter data sets (Verbeek, 2004), a lag length of three was chosen for feeder heifers. Equation 5.9 shows the price equation model where $P^H{}_t$, $P^S{}_t$ and $P^C{}_t$ represent the price estimated at time t for feeder heifers, feeder steers and cull cows respectively, P_{t-n} is the price lagged n years and ε_t is the error term.

Table 5.20 - AIC and SIC values for beef price equations

	Feeder Heifers		Feeder Steers		Cull Cows	
Lag	**AIC**	**SIC**	**AIC**	**SIC**	**AIC**	**SIC**
1	5.0582	5.1418	5.2174	5.3010	4.9236	5.0072
2	4.9375	5.0642	4.9770	5.1037	4.6485	4.7752
3	4.9364	5.1070	5.0221	5.1927	4.4158	4.5864
4	5.0087	5.2242	5.0255	5.2409	4.4715	4.6869
5	5.0955	5.3568	5.0612	5.3225	4.5534	4.8146
6	5.0259	5.3339	5.1146	5.4225	4.5443	4.8522

$$\begin{aligned}
P_t^H &= \gamma_0 + \gamma_1 P_{t-1}^H + \gamma_2 P_{t-2}^H + \gamma_3 P_{t-3}^H + \varepsilon_t^H \\
P_t^S &= \gamma_0 + \gamma_1 P_{t-1}^S + \gamma_2 P_{t-2}^S + \varepsilon_t^S \\
P_t^C &= \gamma_0 + \gamma_1 P_{t-1}^C + \gamma_2 P_{t-2}^C + \gamma_3 P_{t-3}^C + \varepsilon_t^C
\end{aligned} \tag{5.9}$$

5.2.6.2 Beef Price Incorporation and Verification

The parameter estimates for the beef price equations generated from SUR are displayed in Table 5.21. The one time period lag was statistically significant at the 1% level and statistical significance varied between price series at different lag lengths and constants. The R^2 values ranged from 0.72 to 0.79. Similar to crop price simulation, initial lagged prices, P_{t-1}, P_{t-2} and/or P_{t-3}, where t=0 had to be specified before the simulated prices, P_0, could be estimated. These initial lagged prices were set equal to the historical mean of the respective data series. Breusch-Pagan and likelihood ratio test did justify the use of SUR with p-values less than 0.0001 from test statistics of 45.95 and 68.26 respectively.

Table 5.22 provides the error correlations between the price equations from Table 5.21. The highest correlation coefficient is between error terms for feeder heifers and feeder steers.

Table 5.21 - Estimated beef price equations

Variable	Estimated Coefficients		
	Feeder Heifers	Feeder Steers	Cull Cows
Lag 1	0.8237***	0.9032***	0.4390***
	0.1272	*0.1292*	*0.1270*
Lag 2	0.0442	-0.1313	0.6752***
	0.1628	*0.1628*	*0.1125*
Lag 3	-0.1397		-0.2669**
	0.1020		*0.1277*
Constant	35.080***	31.921**	7.9511
Std Error	11.986	12.276	8.974
R^2	0.7192	0.7181	0.7908

*** = significance a 1% ** = significance at 5% * = significance at 10%

Table 5.22 - Estimated beef price estimation equation error correlations

	ε_t^S	ε_t^H	ε_t^C
ε_t^S	1		
ε_t^H	0.8826	1	
ε_t^C	0.6341	0.5931	1

To test whether the assumption of stationary price series was a realistic assumption for beef prices, the simulated price for year twenty was compared to the historical mean of the respective prices series. A stationary process used in the simulation analysis will result in a trend in beef prices towards a long run mean. If the econometric analysis was estimated correctly, this long run value should approximate the historical price series mean. Table 5.23 shows these two values (i.e., the average year 20 price and the historical mean price). The simulation results are approximately equal to the historical mean, suggesting that the beef price models do a good job of representing the long run mean price. The assumption of stationarity in the price series therefore does not seem to be problematic.

Table 5.23 - Comparison of historical price data and @risk expected value for beef prices in year 20 ($/cwt)

	Heifers	Steers	Cull Cows
Historical Mean	135.1	146.4	69.1
@Risk Simulated Mean	130.2	142.1	67.9

Due to the stochastic nature of the model, calf weights were variable from year to year depending on the length of the grazing season, as explained in section 5.1.2.2.1. A longer grazing season may result in weaned calves that are heavier than 600 pounds. Calves in this weight class would be sold at a different price than calves that are between 500 and 599 pounds. To account for this possibility, simple ordinary least squares (OLS) equations were estimated with the price for alternative weight classes (4-5 cwt, 6-7 cwt, 7-8 cwt) as the dependent variable and the price for 5-6 cwt calves as the explanatory variable. The results from these estimations are provided in Table 5.24. All coefficients and most constants are statistically significant at the 1% level. The R^2 values are very high, demonstrating the high correlation between prices in different weight classes. If the simulation resulted in calves to be sold with weights that are not in the 5-6 cwt class, the simulated beef price was adjusted using these regression equation results in order to obtain the relevant selling price.

Table 5.24 – Estimated price equations for alternative steer and heifer weight classes

Variable	Heifer Price Estimation			Steer Price Estimation		
	4-5 cwt	**6-7 cwt**	**7-8cwt**	**4-5 cwt**	**6-7 cwt**	**7-8cwt**
5-6cwt Price	1.1238***	0.9033***	0.7588***	1.1027***	0.8836***	0.7611***
	0.0300	*0.02442*	*0.0263*	*0.0398*	*0.0233*	*0.0312*
Constant	-9.8853**	6.7996**	18.8890***	-6.3061	8.7095**	17.6530***
Std. Error	4.0199	3.2672	3.5334	5.5268	3.2256	4.3385
R^2	0.9742	0.9737	0.9574	0.9539	0.9750	0.9412

*** = significance at 1% ** = significance at 5% * = significance at 10%

5.3 Economic Relationships

Figure 4.4 in Chapter 4 illustrates the economic relationships modelled in the simulation analysis. These relationships are included in order to calculate the NPV associated with alternative BMP scenarios. Underlying the NPV analysis is a cash flow measure, specifically a modified net cash flow (MNCF), that is computed as the measure of farm performance. MNCF, in terms of what is included in this measure, is in between a gross margin and a net cash flow measure. Revenues and expenses associated with the various farm enterprises are included in the MNCF calculation, as are cash inflows and outflows associated with public risk management safety net programs (i.e., crop insurance and CAIS). Also included in MNCF is a constant cash outflow (equivalent to depreciation) that is attributed to machinery maintenance/replacement, as discussed in Chapter 4. In this section of Chapter 5, the revenue, expense and public safety net program components of MNCF are outlined and discussed. Revenues include crop, forage and calf or cull cow sales as well as government program payments. Costs include all cash variable input costs for crop and beef production, the cost of machinery ownership and others associated with an agricultural enterprise.

5.3.1 Revenues

The main revenue stream for the representative farm is generated from crop and calf sales; this makes up approximately 80% of total revenue over the 20 year simulation period. Other revenues included proceeds from the sale of hay and barley silage, in years where inventory levels reach the threshold level, and cull cow sales. Another source of revenue was crop insurance payouts and Canadian Agriculture Income Stability (CAIS) program payouts. These are described later in this section.

Crop revenues in each year were calculated by multiplying the simulated crop yield by the respective annual crop price, and then summing across all crops. Forage revenues were equal to the quantity of excess inventory multiplied by the forage price, again summed across the types of forage.

Revenues for the cow/calf enterprise consisted of the proceeds received from selling market heifers, market steers and cull cows. These revenues were calculated by multiplying the relevant beef price (i.e., heifer, steer or cull cow) by the market weight, summed across animal types. Revenues may be realized at different times of the year depending on when the animal is sold. Market calves may be sold off grazing if the desired market weight is reached or later in the fall when they have reached market weight in the drylot[17]. Cull cows can be sold at two different times in the year depending on whether they have conceived after breeding or produced a calf after weaning[18].

5.3.2 Input Costs

Input costs are the costs of any inputs that are used directly in the production of a good or service. In the study, these inputs would include fertilizer and chemicals, labour, veterinary costs, trucking costs, machinery and building repair costs, etc. The input costs for the representative farm were established based on regional beef farm profiles provided by Alberta Agriculture and Food (Kaliel, 2007), and Agriculture and Agrifood Canada (Ross, 2007). The cost profiles were developed from survey data from farmers and ranchers in southern Alberta. Between the years 2005 and 2007, the producers who were surveyed provided information about their production practices and the costs associated with those practices, so that detailed financial reports representing the geographical area could be developed.

The resulting input costs provided were assumed to be representative of southern Alberta cow/calf operations with forage production, and southern Alberta cropping enterprises. For the crop enterprises and any activities related to crop and forage production, input costs were calculated on a dollar per acre basis for each crop, forage and pasture type. These costs are shown in Table 5.25. Table 5.26 shows input costs associated with cow/calf production, which were reported on a $/head basis.

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[17] See section 5.1.2.2.1 for a full explanation.
[18] See section 5.1.2.2.2 for a full explanation.

Three items in the input cost tables warrant further explanation. Custom work and paid labour costs for both the crop and cow/calf enterprise were included, due to the large size of the farm. The representative farm is sufficiently large that some extra personnel may be hired to assist in performing day-to-day activities. Custom work includes contracting out some farm activities such as grain trucking, manure spreading, etc. The cattle purchases cost included in Table 5.26 represents the expense associated with purchasing replacement bulls for the herd.

As explained in section 5.1.4, there are costs included that are associated with the machinery complement. As discussed earlier, a representative machinery complement was established for the farm, incorporating equipment that would be used to perform the day-to-day farming tasks. All the management decisions associated with the machinery asset base such as buying and selling decisions and machinery depreciation are summed up in a single cost value. This value is derived using the asset value of the machinery base and a depreciation rate. The machinery complement for the farm is valued at approximately $1,400,000. With an 8% depreciation rate, the yearly machinery complement cost is equivalent to approximately $112,000 per year, which is included in the MNCF calculation. Besides this amount, there is a cost included for machinery repairs in Tables 5.25 and 5.26. Machinery repair costs are assumed to be over and above the machinery complement replacement/maintenance cost. Minor machinery repairs and/or part replacements may occur over a growing season or year and the machinery repair cost takes that into account.

Table 5.25 - Input costs associated with the crop enterprise ($/acre)

	Spring Wheat	Durum Wheat	Canola	Barley	Fallow	Green-feed	Alf/Grs Hay	Barley Silage	Tame Pasture	Native Pasture
Seed	8.34	8.34	20.73	7.01	6.86	4.56	9.42	7.01	0.00	0.00
Fertilizer	31.50	31.50	36.50	27.30	10.78	15.49	9.10	7.92	0.00	0.00
Chemical	8.65	8.65	4.09	5.65	4.55	0.00	2.56	0.00	0.00	0.00
Trucking/ Marketing	2.58	2.58	9.22	3.59	0.29	0.00	0.08	0.05	0.00	0.1
Fuel, Oil & Lube	5.35	5.35	5.09	5.23	5.16	6.87	12.44	5.35	0.07	0.14
Machinery Repairs	6.84	6.84	4.74	5.58	8.07	6.66	10.63	7.37	0.15	0.08
Building Repairs	0.62	0.62	0.14	0.47	0.07	0.78	0.33	0.71	0.19	0.17
Utilities & Misc	8.33	8.33	2.28	8.45	3.46	4.37	3.08	3.47	0.13	0.12
Custom Work	1.61	1.61	0.00	3.6	12.46	0.09	2.90	0.00	0.00	0.00
Paid Labour	3.02	3.02	2.86	1.78	6.13	5.81	5.22	5.07	0.46	0.38

Source: Kaliel (2007), Ross (2007)

Table 5.26 - Input costs associated with the cow/calf enterprise ($/head)

Bedding	5.68
Trucking/ Marketing	20.00
Fuel, Oil & Lube	14.00
Machinery Repairs	10.00
Corral & Building Repairs	8.00
Utilities & Misc	17.00
Custom Work	1.50
Paid Labour	45.00
Vet. & Medicine	14.00
Cattle Purchases	42.26

Source: Kaliel (2007), Ross (2007)

5.3.3 Crop Insurance

A production based insurance program was included in the simulation. In 2005, crop insurance receipts made up approximately 2% of Alberta's total farm cash receipts (AARD, 2008-d). During the drought years of 2002 and 2003, crop insurance receipts were 6.0% and 7.7% of Alberta's total farm cash receipts respectively. Though this may seem quite small, given the fact that Alberta's main agricultural sector is beef, having up to 7.7% of gross farm receipts being generated from crop insurance is substantial. It is an indication of the importance that crop producers place on the ability to insure crop yields in Alberta. Therefore it was appropriate to include crop insurance in this analysis.

The basic structure of the Agricultural Financial Services Corporation (AFSC) crop insurance program was followed in the simulation analysis. AFSC's production based insurance program provides protection to producers when the annual crop yield falls below a percentage of what is normally grown. (AFSC, 2008) Producers have four different coverage levels to choose from (50%, 60%, 70%, 80%) to help choose a policy that suits their farm situation

Crop insurance is a risk reduction strategy for producers that protects them from low crop yield possibilities. A producer must choose a protection level and pay the premium associated with that protection level. The higher the protection level, the higher the premium to be paid. If the realized yield in a growing season falls below a pre-determined expected crop yield value, then a payout is made to the producer. For example, if the pre-determined expected canola yield is thirty bushels per acre and the actual yield is twenty bushels per acre, the producer receives an insurance payout that can cover up to 80% (depending on the chosen coverage level) of the loss in revenue between twenty and thirty bushels per acre of canola.

The predetermined crop yield output is representative of the historical crop yield average for the geographical area. More specifically, coverage is determined using a comparison process known as "indexing" (AFSC, 2008). Annual crop yields are recorded and compared to the area average for each crop produced in the area. This indexing process allows for stable coverage from year to year (AFSC, 2008).

In the simulation model, if the actual crop yield for a particular year is below the predetermined crop yield, a payout is triggered based on the coverage level, the size of the difference between the predetermined and actual crop yield and the insurance price for the specific crop. This is best illustrated with an example. If a producer chooses an 80% coverage level and the realized canola yield per acre is five bushels below the pre-determined yield, the producer will receive a payout covering four bushels/acre lost (5 bushels/acre*80% coverage). The number of bushels protected is multiplied by the insurance spring floor price given by AFSC for canola. This price is derived from a formula set based on the historical, current and future price expectation of the crop. If the spring insurance price for canola is \$12.00/bushel, then the producer would receive \$48.00 for every acre of canola seeded (4 bushels/acre*\$12.00/bushel). The producer premium is based on the same factors and is equal to 4% of the total dollar coverage value. If the producer in the above example wants to insure 100 acres of canola at the 80% coverage level at a \$12.00/bushel floor price, the total dollar coverage is:

$$100 \text{ acres}*30\text{bushels/acre}*\$12.00/\text{bushel}*80\%*4\% = \$1152.00 \qquad (5.10)$$

In the simulation, the producer is assumed to choose an 80% crop insurance protection level in each year. The threshold crop yield used to determine if a payout is triggered was calculated based on the historical average of simulated crop yields. For example, in year six, the threshold crop yield is the average of the previous five years simulated yields. If a payout was triggered, the price used to calculate the dollar payout was the 2007 spring floor price from the Agricultural Financial Services Corporation. These prices were \$7.17, \$2.57, \$4.82, \$4.22 for canola, barley, durum wheat and spring wheat respectively.

5.3.4 Canadian Agriculture Income Stability Program (CAIS)

CAIS is a government program that is designed to help protect producer income from weather and disease risk as well as market risk. Producers receive a CAIS payment when their current year's farm income (as defined for the purposes of CAIS) is less than an average based on the previous five years. The income figure used for CAIS calculations is referred to as the production margin; it represents the producer's allowable income less allowable expenses.

In order to determine if a program payment is triggered, the production margin for the current year is compared to the reference margin. The reference margin is the average production margin calculated over the previous five years, after removing the high and low values; that is, the reference margin is actually a three-year average.. If the production margin is lower than the reference margin, then there is potential for a CAIS payment to be triggered. The actual "mechanics" of calculating the payout have changed since the inception of CAIS, as this program has gone through considerable adjustments over the last few years.

Similar to crop insurance, CAIS offers producers a number of different coverage levels. The higher the coverage level, the larger the producer premium needed to participate in the program. However, with a higher coverage level also comes an increased opportunity for a government payment if the producer suffers a difficult year. For the version of the program modeled in this study, there are three coverage levels, referred to as tiers. These tiers represent different protection levels. If the production margin relative to the reference margin is sufficiently low, then a payment is made. The "top" tier, Tier 1, provides coverage if the production margin is between 85% and 100% of the reference margin. Within this tier, payments are made equal to 50% of the shortfall. The next tier, Tier 2, provides coverage for production margins that are between 70% and 85% of the reference margin. Payments within this tier cover 70% of the shortfall up to the top of the tier (i.e., 85% of the reference margin). Tier 3 provides coverage if the production margin is between 0% and 70% of the reference margin, with payments within this tier covering 80% of the shortfall up to the top of the tier (i.e., 70% of the reference margin).

In 2008, the CAIS program changed in terms of the maximum protection level.[19] As of 2008, the maximum level of coverage available is 85% of the reference margin. In other words, the production margin is required to drop to at least 15% below the reference margin before a government payment is triggered. This is the coverage level (i.e., 85%) assumed to be chosen by the producer in the simulation analysis.

The cost to participate in the program is based upon the chosen coverage level. Once the reference margin has been determined, the producer premium is calculated. A $4.50 fee is charged for every 1000$ of the reference margin that is chosen to be protected. An additional $55.00 administration fee is then added. For example, if the reference margin is $100,000 and the producers choose the highest coverage level (85%), then the premium to participate in the program is (AAFC, 2007):

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[19] Along with the change in program structure, CAIS also had its name changed in 2008, to Agristability. This was done in conjunction with the updating and renewal of the Agricultural Policy Framework by the Canadian government. Besides the changes to CAIS/Agristability, a new safety net program was introduced (AgriInvest) and production insurance was renamed AgriInsurance (AAFC, 2008).

$$(\$100{,}000/\$1000)*0.85*\$4.5 + \$55.0 = \$437.50 \quad (5.11)$$

The calculations for CAIS payments can be illustrated with an example. With an 85% coverage level, if the producer's reference margin is $100,000 and the production margin for a particular year is $75,000, then the possible payment received by the producer is (Cortus, 2005):

$$((\$100{,}000*.85)-75{,}000)*0.7 = \$7{,}000 \quad (5.12)$$

Similarly, if the reference margin is $100,000 and the production margin in a particular year is $40,000, the payment is:

$$((\$100{,}000*.85)-(\$100{,}000*0.70))*0.7 + ((\$100{,}000*0.7)-40{,}000)*0.8$$
$$= \$10{,}500 + \$24{,}000 = \$34{,}500 \quad (5.13)$$

In some years, it is possible that the production margin could be less than zero. Under CAIS, rules for coverage were different in this situation. Payments are not made to producers if their production margin is negative in more than two out of any five year period and the coverage was capped at 70%. The version of CAIS modeled in this study incorporated this provision as well.

5.3.5 Discount Rate for Analysis

Section 4.1.3.1 described the approach used to determine the discount rate for the NPV analysis; specifically, a Capital Market Line (CML) approach is taken. The information required to use the CML formula are the volatility of returns for the farm (σ_p), a risk-free rate of return (r_f), and the expected return and standard deviation of returns for the "market" ($\overline{r_m}$ and σ_m, respectively). An initial simulation of the representative farm provided an estimate of volatility, σ_p, which was 18.06%. For the market returns, results from Ross et al. (2005) were used. Their study estimated the expected return from the Canadian stock market, the risk premium (i.e., $\overline{r_m} - r_f$) and the standard deviation, from 1973 to 2003. Using these results, expected market return, $\overline{r_m}$, standard deviation of market returns, σ_m, and the risk premium associated with this return, $\overline{r_m} - r_f$, were calculated as 10.64%, 16.41% and 3.84%, respectively. The yield on a one year Government of Canada Treasury Bond on February 26, 2008, from the Bank of Canada, was used as the risk-free rate of return (r_f). This yield was 3.23%. The expected rate of return ($\overline{r_p}$) for the farm was then calculated as:

$$\overline{r_p} = r_f + \left[\frac{\overline{r_m} - r_f}{\sigma_m}\right]\sigma_p,$$

$$3.23\% + \left[\frac{3.84\%}{16.41\%}\right] * 18.06\% = 7.5\% \qquad (5.14)$$

which, assuming that the assumptions underlying the use of the CML are valid, is the appropriate discount rate for use in the NPV analysis.

Given the absence of studies simulating economic performance of a mixed farm operation, there were no values to use for comparison/verification of this discount rate. Historically, analysis of the type considered in this study was performed on either grain or livestock operations. Miller (2002) and Bauer (1997) used discount rates of 10.21% and 12.34%, respectively, for cattle operations. Simulating a grain operation, Cortus (2005) determined 13.91% to be the discount rate, following a similar CML approach. However, in his simulation analysis Cortus chose to use a 10% discount rate as that was commonly used in previous drainage decision studies (Danielson and Leitch, 1986; Leitch, 1983; Rigaux and Singh, 1977; Found et al., 1975).

Within the simulation, volatility estimates of the crop and beef enterprise were also available. Individually, the crop and beef enterprises exhibited volatilities of 23.26% and 15.35%, respectively, in the initial simulation. Substituting these values into equation 4.8 produced a discount rate of 8.7% for the crop enterprise and 6.8% for the beef enterprise. The beef enterprise discount rate is in line with Stillings (2000) who used a 7% discount rate to analyze riparian grazing management strategies on the total gross margin for a 300 head cow/calf operation.

Contrary to the resulting discount rates for each enterprise, Cortus (2005) argues that grain operations have a lower level of risk compared to livestock operations due to the opportunity for producers to produce a number of different crops. That is, producers can shift acreage to crops that have forecasted higher prices. Cortus (2005) does not, however, take into account that the ability to switch between crops is largely dependent on soil quality and type. A Class 1 soil type has no significant limitations on the types of crops that can be planted. As the soil class rises, the range of crops that can be produced drops substantially thus decreasing the ability to switch between crops[20]. Ahrendsen et al. (2006) report that crop income is more variable than livestock income due to the larger impact that weather can have on crop enterprises over livestock enterprises. It is expected that the likelihood of a loan loss for a financial lender is larger for a farm with more crop income relative to one with more livestock income and crop farms have a greater demand for operating loans than livestock farms (Ahrendsen et al., 2006; Dixon et al., 1997). The volatility estimates for the crop and livestock enterprises in the representative farm support Ahrendson et al., that is, crop production is riskier than livestock production.

Ultimately, a discount rate of 10% was used for the analysis based on the previous studies mentioned above. A sensitivity analysis on discount rates was performed, however, to test for the impact of this choice. The sensitivity procedures are described in section 5.4.5, and the results are reported in the next chapter.

5.4 Best Management Practices

The purpose of this study is to analyze the economic costs/benefits of best management practice implementation. This section describes the best management practices that were implemented on this farm and how they were modelled in the simulation. BMPs are implemented for the crop enterprise and the cow/calf enterprise. They are done in an order such that a progression is followed to be more protective of the riparian area and water with each additional BMP.

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[20] Appendix I shows soil classifications.

5.4.1 Cropland BMP Scenarios

BMPs on cropland were implemented in an effort to reduce the possible contamination of riparian areas and water from the leaching of fertilizers, chemicals, etc. and the impact of cattle. The cropland on this farm is subject to aftermath grazing from cattle after harvest so there is a potential impact of these animals having access to riparian areas and waterways. Cropping activities near riparian areas and waterways are known to transmit fertilizers, chemicals etc into drinking water supplies (Table 2.1).

A number of assumptions are made for cropland BMPs. It is assumed that initially, before implementation of the BMPs, the producer is able to seed and harvest crops on all land available, including right up to water's edge of the river. The soil and topography on or near the riparian area is assumed to be as suitable for crop production as upland areas. The risk of stream bank flooding and other acreage losses is assumed to be negligible.

In order to proceed with BMP analysis, the size of the riparian area had to be defined. There are many factors contributing to the size of a riparian area, such as the size and flow intensity of the stream of river. Riparian zones may be small for forest embedded rivers, while mid to large size streams may have complex riparian zones as a result of long term hydrological, vegetative and soil dynamics (Naiman and Decamps, 1997).

From various studies and reports, the appropriate width of the riparian zone along a stream bank has been defined to be anywhere from 30 to 90 feet (GWA, 2000). A study done by the Government of Prince Edward Island (1997) concluded that riparian zones adjacent to waterways should be a minimum of 10 metres. Hutchins (1998) split riparian zones into 3 parts. Zone 1 includes all land area from the water line extending fifteen feet out; vegetation in this zone includes trees and shrubs. Zone 2 is an extension on Zone 1 by 20 feet, and includes trees, shrubs and grassy plant material. Zone 3 extends a further 20 feet and is a grass buffer zone that can be cropped or rotationally grazed. The actual width of a riparian zone in a particular area depending on slope, soil type and adjacent land use activity and is the last defence to protect water bodies from land usage effects.

Based on the literature and discussion with Carlyle Ross at Agriculture and Agri-food Canada, it was decided that the riparian area for this study is defined as being 30 feet in width. Thus, the first step in implementing any of the following BMPs was to convert the first 30 feet of land from the water's edge back to riparian habitat.

There are three BMP options that are implemented on cropland in this study. These represent increasing degrees of protection for the riparian area. The first BMP considered is conversion of cropland to permanent cover (allowing aftermath grazing). The second cropland BMP is conversion to permanent cover with exclusion of cattle. The third cropland BMP is conversion of cropland to a buffer strip. These BMPs are described in more detail in the following sections.

5.4.1.1 BMP #1: Conversion of Cropland to Permanent Cover

The first BMP considered is converting cropland on and near a riparian area to permanent cover. Cropland is any land that is producing crops or silage. Permanent cover is a term used to define land that is subject to no-till conservation practices. More specifically to this study, permanent cover refers to land that is used to permanently produce hay. Once a hay stand is established, there is much lower fertilizer or chemical input use and soil disturbance is greatly reduced as yields are harvested.

Beyond the riparian zone, BMPs should be implemented to reduce the impact of upland activities on riparian areas. Therefore, once the first thirty feet has been converted to riparian habitat, another thirty six feet is converted to permanent cover. Thirty six feet was chosen for the permanent cover strip due to swather header size[21] and ease of harvesting the hay. The permanent cover is alfalfa grass hay; that is, the type of hay already produced for forage on the farm. During harvest, this crop is swathed and baled. Figure 5.3 demonstrates the transition pattern for this BMP, from the stream out to the upland area.

This BMP protects riparian zones and water from the effects of cropping activities. However, livestock that will aftermath graze on crop residue still have complete access to all acreage. The livestock impact on riparian area may be minimal as the aftermath grazing occurs in the fall where the riparian zones are less sensitive to livestock intrusion (Soulodre, 2007). However, the water is still vulnerable to these impacts.

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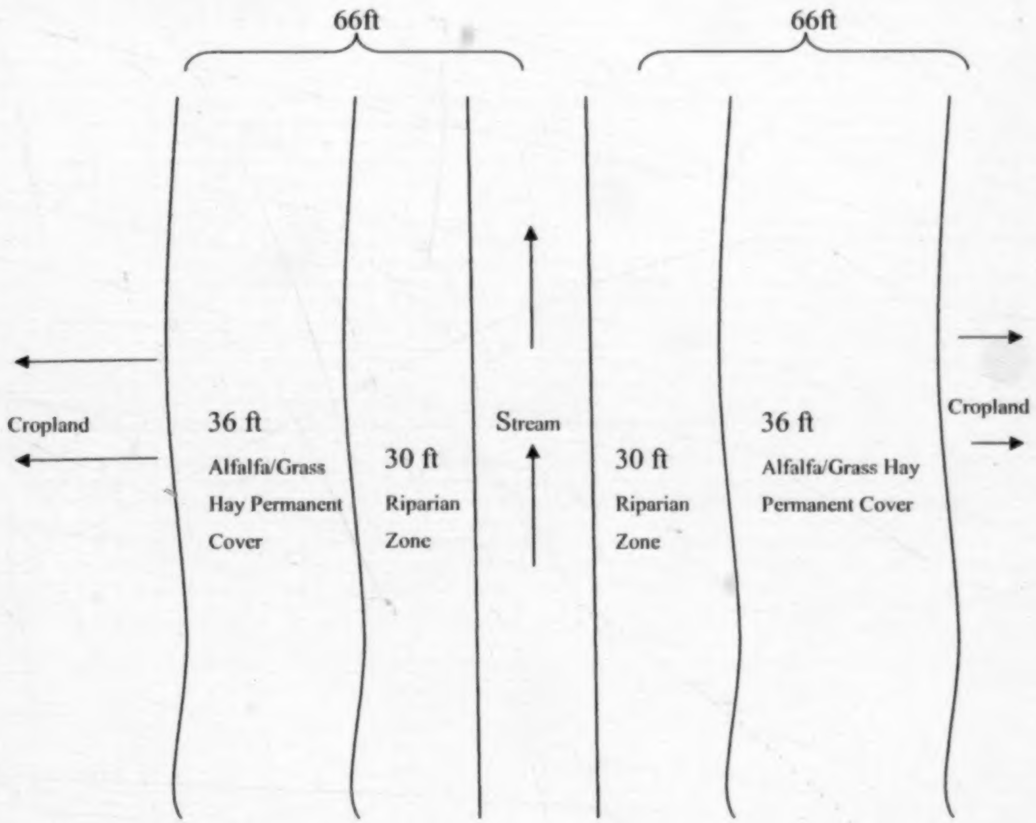
[21] Appendix C provides information about the machinery complement.

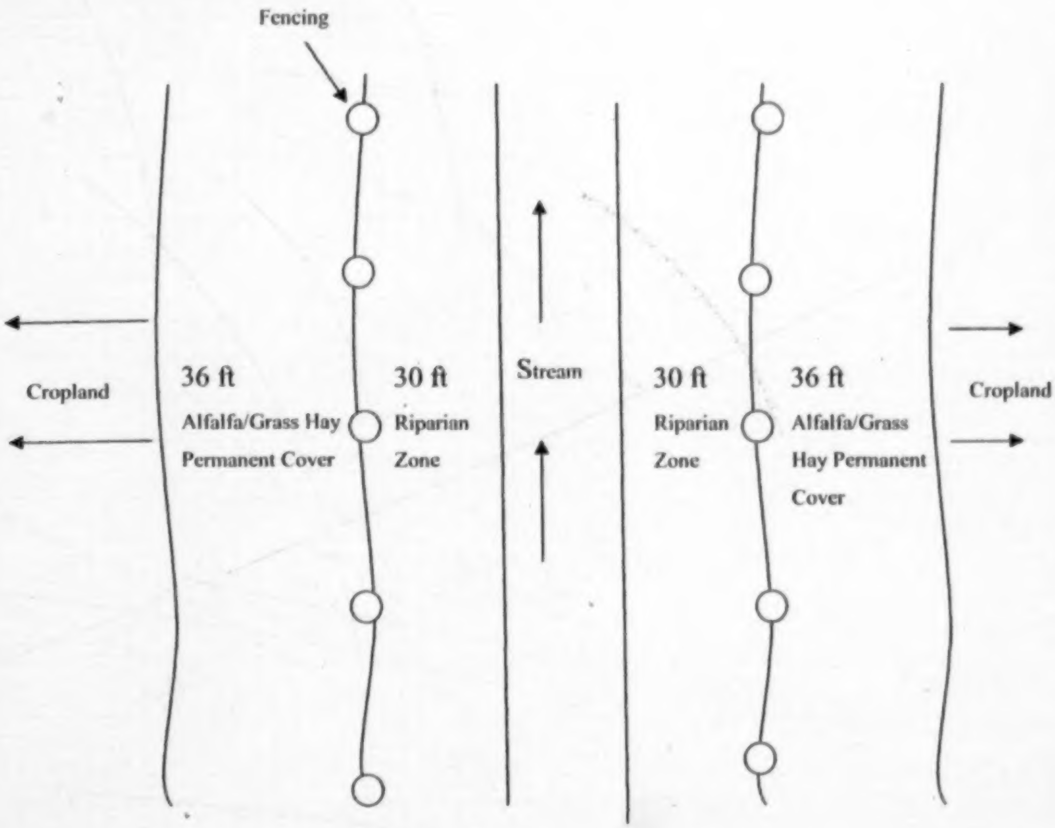
Figure 5.3 - Diagram of BMP #1


66ft
66ft
Cropland
36 ft
Alfalfa/Grass
Hay Permanent
Cover
30 ft
Riparian
Zone
Stream
30 ft
Riparian
Zone
36 ft
Alfalfa/Grass Hay
Permanent Cover
Cropland

5.4.1.2 BMP #2: Conversion of Cropland to Permanent Cover with Cattle Exclusion

The second BMP (BMP #2) is similar to the previous BMP, but includes an additional degree of protection. To control livestock impact on riparian zones and water ways during aftermath grazing periods, BMP #2 includes fencing along the riparian zone to restrict cattle access. A permanent fence is established between the riparian zone and permanent cover (Figure 5.4). The cost of fencing is based on a $/foot basis and details of the cost are provided in appendix J. For all BMPs where fencing is incorporated, it is assumed that it will take three years to complete the fencing. For example, if 750 metres of riparian zone needs to be fenced, 250 metres will be fenced and protected per year. After year three, it is assumed that all desired riparian areas are protected. Figure 5.4 illustrates the pattern of conversion and protection for BMP #2.

Figure 5.4 - Diagram of BMP #2

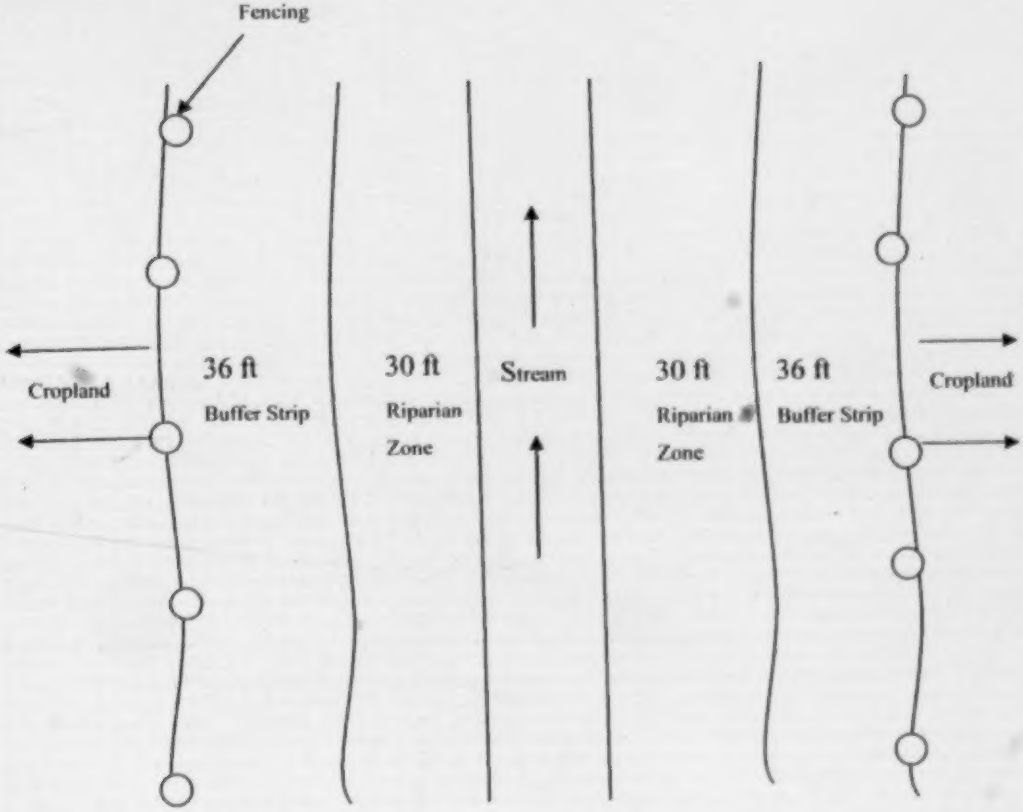

Fencing
Cropland
36 ft
Alfalfa/Grass Hay Permanent Cover
30 ft
Riparian Zone
Stream
30 ft
Riparian Zone
36 ft
Alfalfa/Grass Hay Permanent Cover
Cropland

5.4.1.3 BMP #3: Conversion of Cropland to Buffer Strip with Cattle Exclusion

For the highest level of riparian zone protection, a buffer strip instead of permanent cover is established on cropland. As explained earlier, a buffer strip is land adjacent to a waterbody or riparian zone in permanent vegetation to control pollutants (USDA, 2000). There is no harvesting of the buffer strip. In the case of this analysis, the implication is that the entire 66 feet out from the stream is lost to cropping activities. Fence is established between the buffer strip and cropland to restrict cattle access to the area as well.

This is obviously the most extreme BMP for cropland with aftermath grazing. While this BMP is definitely an option for producers it may not be readily adopted due to the loss of productive land for crops and grazing (Soulodre, 2007). However, it would be a consideration for implementation if there were serious riparian health problems and water quality issues. Because of this, and also because of the value in considering the full range of options for producers in terms of impacts and costs, this BMP was included in the analysis. Figure 5.5 illustrates the pattern of land use change for this BMP

Figure 5.5 – Diagram of BMP #3


Fencing
Cropland
36 ft
Buffer Strip
30 ft
Riparian
Zone
Stream
30 ft
Riparian
Zone
36 ft
Buffer Strip
Cropland

5.4.2 Cropland BMP Sensitivity

For modelling purposes, it was assumed that 2% of total farm acreage is classified as riparian acreage. Research has concluded that up to 2% of rangeland is an appropriate estimate of the size of a riparian area in a given land area (Fitch and Adams, 1998; Kreuger, 1984). It is understood, however, that the riparian zones may be bigger or smaller depending upon the farm's situation. Unterschultz et al. (2004) used a range of riparian area sizes from 1% to 7% of total range area while analyzing the economics of adopting grazing strategies to improve riparian grazing capacity. The sensitivity analyses in this study do not include varying the size of the riparian zones. Given the previous literature and studies on riparian management, 2% was deemed an appropriate value and subsequently used in this study.

While the amount of riparian area present on the farm is not changed for the purposes of sensitivity analysis, the degree of protection implemented is varied. It is not realistic to assume that all riparian acreage will necessarily be protected on farms, especially on a farm of this size. As a result, the analysis includes simulations that examined a range of riparian protection levels; 25%, 50%, 75% and 100%. These protection levels represent how much of the riparian acreage on cropland is protected from cropping and grazing activities through the use of permanent cover or buffer strips and fencing. The 25% protection level implies that the BMPs will be implemented to protect 25% of the designated riparian zones on cropland. The 100% protection level implies that all of the riparian acreage on cropland will be protected.

The riparian coverage sensitivity analysis will show what can be expected in terms of costs to the farm with different coverage levels. As the protection level increases, more productive cropland is converted to riparian acreage and permanent cover which is hypothesized to have an impact on a number of economic and bio-physical relationships. One obvious impact will be on crop sales. An increase in the protection level will decrease crop sales with the lower crop acreage. However, this will also lead to a decrease in crop input costs which are calculated on a per acre basis. With a reduction in crop production from implementation of BMP #1 and BMP #2, there is an increase in hay production which will impact the cow/calf enterprise and the supply of winter feed. With higher protection levels, more hay will be available for feed and/or sale. With the implementation of BMPs #2 and #3, the implementation of exclusion fencing on aftermath grazing acreage may lead to a reduction in the grazing season. This, in turn, will impact calf weights and lengthen the winter feeding time. Further outcomes and results of cropland BMP implementation will be explored in the following chapter.

5.4.3 Pastureland BMP Scenarios

BMPs were implemented on pasture land in an effort to reduce livestock impact on riparian zones and water quality. Chapter 2 provides a discussion of previous research that has shown benefits of these BMPs on riparian areas in grazed pastures. Three alternative pasture BMPs are considered in this study. As with the cropland BMPs, they also follow a progression from least to most protectionist.

5.4.3.1 BMP #4: Off-Stream Watering (OSW)

The benefits of providing clean fresh water to livestock have been extensively researched (see Section 2.4.1). The results of this research have shown there are proven productivity improvements in terms of calf and cow weight increases and better livestock health, resulting from improved quality of water provided to the animals. This BMP established off-stream watering (OSW) sites for grazing livestock on the representative farm. There are no other changes made in terms of protecting riparian areas and removing animals from streams banks, etc. Simply providing an OSW site can encourage livestock to leave riparian areas and utilize upland areas more effectively (Porath et al., 1997; Sheffield et al., 1997; Clawson, 1993). The cost of these sites varies by type of site and equipment used. Expert opinion was used to estimate the costs associated with establishing OSW sites for the representative farm. Etienne Soulodre of the Saskatchewan Water Authority suggested generalizing the cost of OSW systems on a $/head basis[22]. This process was followed and the cost of an OSW site for the large herd size on the representative farm was calculated to be $65.56/head. Appendix K shows the source of the cost data and how these data were used to derive the per head cost. For this analysis, there was no need to determine the logistics of OSW site placement on the pasture. It is assumed that the OSW sites were placed in optimal locations, but the specific locations did not have a direct bearing on the simulation analysis.

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[22] Soulodre suggested an OSW cost of approximately: 1) $3,000 for a 30 to 50 cow herd, 2) $6,000 for a 100+ cow herd and. 3) $14,000+ for a herd size greater than 400 cows.

5.4.3.2 BMP #5: Off-Stream Watering with Temporary Access Fencing

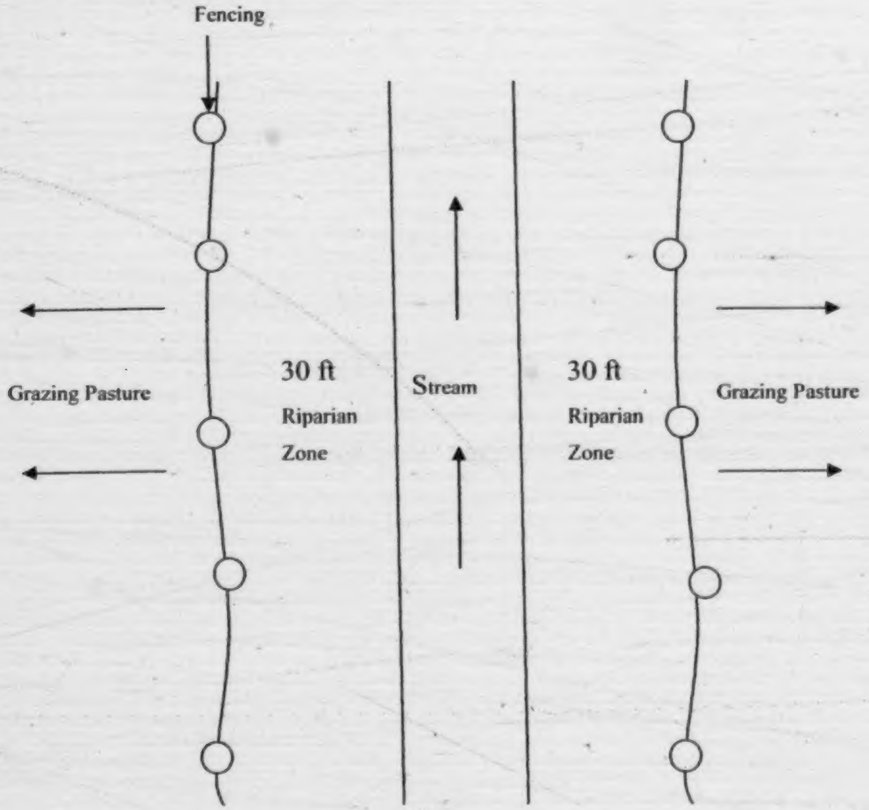
This BMP increases the protection for riparian areas in grazing pastures. Fencing is established, similar to BMP #2, thirty feet from the stream. This allows for the replenishment of riparian areas that usually are subject to trampling, etc. by livestock. The producer is subject to the cost of installing and maintaining fencing which will impact the profitability of the farm.

However, this BMP acknowledges the balance that can be found between both protecting riparian ecosystems and utilizing its potential. As a result, livestock are not completely excluded from the riparian areas. It is assumed that during certain times of the year the riparian areas are able to be utilized for grazing and will not be severely damaged by livestock. Grazing intensity and use are large determinants of how a riparian area will change due to livestock access (AARD, 2007-c). The longer the animals are in riparian areas, the more damage they can do to the site. The key to preserving riparian vegetation health is to leave sufficient above-ground growth after grazing.

A good option is to let cattle graze riparian vegetation for a day or two and then remove them from the site (AARD, 2007-c). The timing of grazing is a very important factor, as wetter soils in riparian areas are much more susceptible to damage than drier soils. These times include after heavy rainfall or during the spring melt (Bellows, 2003-a; Gifford et al., 1977). Riparian grazing is most detrimental to vegetation and soils when vegetation is in early stages of growth and soils are soft. Soft soils are greatly impacted by trampling and soil compaction at these times. The best times to graze these pastures are during drier periods or late season grazing when vegetation has been well established (AARD, 2007-c). Rotational management of riparian areas needs to be enforced to take advantage of riparian grazing while still protecting the riparian areas. The drawback is that livestock are still able to enter waterways and pollute the water.

With this BMP, the rotational grazing ability is provided by installing a gate or fence that is used to open up the riparian areas to cattle. Figure 5.6 illustrates the implementation of this BMP. In reality, some situations may include an open gap that allows for cattle to cross from one pasture to the next through the waterway but the figure below provides a general example of what the BMP implementation may look like. This BMP is a continuation of the progression towards full riparian protection.

Figure 5.6 - Diagram of BMP #5 and BMP #6


Fencing
Grazing Pasture
30 ft
Riparian
Zone
Stream
30 ft
Riparian
Zone
Grazing Pasture

5.4.3.3 BMP #6: Off-Stream Watering with Cattle Exclusion

The final BMP for pasture land is a represents an increase in the degree of riparian protection from BMP #5. This BMP completely excludes any cattle from accessing riparian areas. The loss of grazing acreage is hypothesized to shorten the grazing season, thus reducing calf weights off grazing and increasing the winter feeding time and winter feed costs. This BMP may not be as likely to be implemented as BMP #5 because of the significant loss of access to riparian vegetation. However, it is useful to compare the cost of implementing this BMP with respect to implementing no BMPs to understand the extreme range of costs incurred or losses in cash flows with different riparian protection strategies (Soulodre, 2007; Ross, 2007).

5.4.4 Pastureland BMP Sensitivity

It is appropriate to conduct an in-depth sensitivity analysis for the pastureland BMPs, given the vast literature that supports the presence of productivity improvement in calf weights and pasture utilization. Chapter 2 describes the possible benefits that a producer may realize by providing off-stream watering sites. The benefits that will be investigated here are increased calf weight gains off pasture and increased pasture utilization.

Sensitivity analysis was performed to understand the impact on the gross margin of increased calf weights off pasture from BMP implementation. If producers can realize a higher calf weight and thus greater revenues, the investment in terms of time and money into BMP implementation may seem more attractive. Simulations were run with a range of calf weights gains from BMP implementation to assess the impact on economic performance. These included 1%, 2%, 3%, 5% and 10% increases in calf weights. This range of values was chosen to support the productivity improvements that were found in studies on grazing management strategies, as discussed in section 2.4.

Sensitivity analysis was also performed on grazing pasture utilization. OSW sites have been shown to draw livestock away from riparian areas and natural sources of water towards upland areas. This improves the distribution of livestock over grazing pasture by exposing livestock to pasture that they may not otherwise utilize if the cattle were concentrated around the water sources in riparian areas. Essentially, the use of an OSW site results in an increased proper grazing factor explained in section 5.2.3.2 which can lead to a longer grazing season. Sensitivity analysis included increasing this grazing factor by 1% or 2% per year for a 3 year period and then sustaining the increased productivity over the remaining years in the time horizon. Increases occurred over time as a producer cannot expect livestock to immediately move upland after OSW sites are established. Riparian fencing is assumed to take three years to complete so the sensitivity parallels this management decision. Consequently, total grazing factor comparisons will include 3% or 6% increases in productivity.

5.4.5 Discount Rate Sensitivity

Due to the lack of certainty in terms of what the appropriate discount rate for an agricultural firm should be, sensitivity analysis will be performed on the discount rates. The base discount rate used in the simulation analysis was 10%, as discussed in section 5.3.5. This value was chosen despite the fact that a discount rate of 7.5% was found to be a better representation of the risk faced by the farm. Therefore, sensitivity analysis will be performed on select BMP scenarios and productivity improvement scenarios, using 7.5% and 12.5% discount rates. This is done to test whether the results associated with BMP implementation and the comparisons with the base non-implementation scenario are significantly affected by the choice of discount rate.

5.5 Simulation, Cash Flows and Revenue/Cost Recognition for BMP Analysis

A brief description of the Monte Carlo simulation procedure, model cash flows and revenue/cost recognition is provided in this section. This is done to clarify how the impacts of BMP implementation described above will be analyzed. The representative farm is composed of two main components; the beef enterprise and the crop enterprise. These two enterprises are treated separately in terms of cash flow calculations, allowing for a clearer, in-depth analysis of the impact of each BMP on each enterprise. However, the two enterprises are also combined to develop a cash flow for the entire farm with all its constituent parts. In some cases it may be difficult to identify how or where BMP implementation has impacted the total farm's cash flows, so breaking up the farm into its basic parts will clarify what producers can expect to happen in different parts of the farm.

The resulting modified net cash flow (MNCF) for the entire farm will be used in NPV analysis as the comparator across BMP scenarios and sensitivities.

5.5.1 Simulation Model Iterations

Monte Carlo simulation uses an iterative process to generate many paths of outcomes for a simulation model. The "result" from this type of simulation is a distribution of possible outcomes[23]. As the number of iterations increases, more possible outcomes are produced, giving a better representation of the range of possible outcomes. However, this comes at the cost of additional time required to run the simulation. Although the run time for the simulation model used in this study is not significantly long, the number of simulation scenarios modeled in this study results in the total time requirement being significant. Thus, an iteration level had to be chosen for the simulation that would accurately and fairly represent a distribution of outcomes, while being efficient from a time perspective.

Trial simulations were compared using 1000 and 5000 iterations. A total of 50 base simulations were run at both the 1000 and 5000 iteration level to test the range of outcomes; that is, the simulation was run for 1000 iterations, and this was repeated 50 times, with the process being replicated for 5000 iterations per run. For comparison, the distributions of outcomes at the 1000 iteration level was plotted against the distribution of outcomes at the 5000 iteration level to determine if there was a large difference in results. The distribution of base farm 20 year NPVs showed no clear evidence to use 5000 iterations over 1000[24]. Therefore, simulations were performed using 1000 iterations to produce distributions of outcomes for use in the BMP analysis.

5.5.2 Enterprise and Whole Farm Modified Net Cash Flows

The crop enterprise and respective cash flows includes all revenues and costs that are associated with crop and/or forage production. These costs include fertilizer and chemical costs, trucking, etc. (Table 5.25 and 5.26) Revenues include the sale of crops and forages. Section 5.1.3 briefly mentions that possibility of selling excess forages to generate a new revenue stream and this is included in the crop enterprise cash flow. The BMPs described above have the potential to impact the amount of forage sales that may be realized by the farm. For example, any BMP that increases the grazing season would subsequently increase the potential for additional forage revenue, since winter feeding days decrease as the length of grazing season increases. The change in forage sales would lead to a change in the cash flow for the crop enterprise in the same direction.

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[23] Refer to section 4.2.2.1 for a more detailed explanation of Monte Carlo simulation.

[24] See appendix L for a histogram comparison of iteration level outcomes.

The beef enterprise cash flow includes all revenues from the sale of heifers, steers and cull cows and all input costs associated with raising those animals (Table 5.26). There are BMPs that will impact these underlying cash flows. Any BMP that increases the weight of gain of calves off of grazing will increase the selling weight and thus calf revenues. Results will show the impact of BMPs on calf weights and grazing season days which will lead to a change in enterprise cash flows.

Cash flows for each enterprise are combined to formulate cash flows for the entire farm over 20 years. The enterprise cash flow analysis is specific to any revenues and costs that are associated with the crop or beef enterprise. These cash flows do not include any CAIS or crop insurance payments or receipts. Government program expenditures and receipts are recognized in the whole farm cash flow.

5.5.3 NPV Calculations and BMP Assessment

Using the NPV formula (equation 4.4 in section 4.1.1.1), net present values are calculated for each enterprise as well as for the entire farm. After all simulations are complete for all scenarios and sensitivities, there are alternative NPVs that can be compared to analyze the magnitude of the costs and/or benefits of BMP implementation.

In particular, there are two NPVs calculated for each simulation. The first NPV calculates the farm's financial performance over the twenty year time horizon. The second NPV is referred to as an NPV with perpetuity. A perpetuity is a stream of cash flows that does not end (i.e., continues in perpetuity). This NPV calculates the performance of the farm in perpetuity; in other words, it calculates the NPV of the farm assuming an infinite time horizon for the business. The NPV with perpetuity takes the nineteen year NPV (i.e., the NPV calculated over the first nineteen years of the time horizon) and adds to it the MNCF for year twenty, discounted with the perpetual annuity present value formula. The calculation for the NPV with perpetuity is as follows:

$$NPV = \sum_{t=1}^{19} \frac{C_t}{(1+r)^t} + \frac{C_{20}}{r} - I_0 \quad , \qquad (5.15)$$

where C_t is the cash flow at time t. At year 20 the perpetuity present value is calculated by dividing year 20 cash flow by the discount rate.

The assumption is made in the model that BMP implementation is done for the long term goal of protecting and maintaining water quality and riparian zones. Even though a 20 year time horizon could be considered long term in an agricultural framework, it is useful and interesting to compare the results under the two alternative time horizons. Thus the two NPVs are calculated and used in BMP analysis.

Before BMPs are implemented into the farm operation for analysis, the NPV will be calculated for the 'base' or 'reference' farm. This will be the NPV value for the representative farm with no BMPs implemented. All of the NPVs for the BMP scenarios will be compared to this value. Assessing the cost and/or benefits of BMP implementation on farm profitability is fairly straightforward once all NPVs have been estimated. Examining the difference between a NPV from a BMP simulation and the base NPV will indicate if implementation provides an net economic benefit or results in a net cost, as well as the magnitude of this benefit or cost. This total difference can be manipulated into a total cost/benefit per acre by dividing the NPV difference by the number of acres converted and/or protected.

The impact of BMP implementation in terms of net benefits or costs can be "annualized" to calculate a yearly change per acre converted using the following formula:

$$C_A = \left[\frac{C_T * r}{\left(1 - \frac{1}{(1+r)^n}\right)} \right], \qquad (5.16)$$

where C_A is the annualized cost or benefit per acre, C_T is the change in NPV between the two scenarios (i.e., between the BMP scenario and the base scenario) expressed on a per acre basis, *r* is the discount rate and *n* is the time horizon of 20 years. For perpetuity NPV calculations, *n* was set to 1000[25].

This formula converts the total cost or benefit per acre to an annual cost or benefit called an annuity. An annuity is a level stream of regular payments that lasts for a number of periods into the future (Ross, 2003). BMP implementation costs occur in the first, second and/or third year depending on the BMP but there are direct effects of this implementation into the future. In this regard, this formula is can also be referred to as the equivalent annual cost. The equivalent annual cost is the annual cost of owning an asset over its entire life and is a useful capital budgeting technique to compare investment projects (Ross et al., 2005). The asset in this analysis is the investment in various best management practices. On this basis, the farm can compare the investment in ownership and operating costs of an array of best management practices and decide which option will be economically feasible.

Net present value analysis and deviations from NPVs and twenty years of modified net cash flows from BMP implementation will be presented with cash flows for the entire farm. A breakdown of the NPV for individual enterprises will also be provided

5.6 Chapter Summary

This chapter outlined the stochastic simulation model developed to analyze the impact of best management practice implementation on a mixed farm in the Lower Little Bow Watershed in southern Alberta. The simulation was composed of a twenty year NPV analysis of modified net cash flows as well as NPVs in perpetuity. The cash flow models were simulated with six possible BMPs and accompanying sensitivity analysis to investigate the economic feasibility of implementation to the producer.

The model was based on a large mixed operation in the Lower Little Bow watershed bordering the Lower Little Bow River that is ideal for BMP implementation studies. The land base for crop, forage and pasture production was replicated as well as the dynamics of the cow/calf herd. The land and farm characteristics determined what type of BMPs are suitable for water quality and riparian health protection.

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[25] An alternative way to calculate the annuity from the perpetuity NPV is applying the formula $C_A=C_T*r$.

The stochastic nature of the model was interpreted through stochastic crop and beef prices as well as weather patterns. Stochastic weather was the explanatory variable in crop yield models. These stochastic variables were used to generate farm revenues. When combined with representative input costs allowed for the ability to simulate a distribution of outcomes to best understand the behaviour of the farm over time. The stochastic inputs were based upon historical data for the region to make the simulation as representative as possible.

The model has the ability to analyze the six BMPs that are considered for implementation on the representative farm in the Lower Little Bow Watershed. These BMPs serve the purpose of protecting riparian habitat and water quality by reducing the impact of cropping activities on riparian habitats and bodies of water, drawing livestock away from riparian habitats and bodies of water, or completely blocking livestock access to riparian habitats and bodies of water. A number of sensitivity analyses are undertaken to further assess the potential economic response to BMP implementation.

Chapter 6 : Results and Discussion

This chapter presents the results and key findings of the simulation scenarios that were introduced and described in Chapter 5. The basis of comparison for all results was the base or reference farm NPV, cash flows and other relevant statistics. These were compared with the results for the farm when a BMP was implemented. The model discussed in the previous chapter produces a large set of output results. In this chapter only the most important results to compare scenarios and sensitivities are presented and discussed. However, all other summary statistics resulting from the various simulation "runs" are provided in Appendix M.

6.1 Best Management Practice Analysis

6.1.1 Reference Farm

All scenarios and sensitivity analyses needed to be compared to a base or reference to discover the costs/benefits associated with implementing various BMPs. The analyses in the sections to follow are all compared to simulation analysis of the representative farm with no BMPs implemented. All the relationships modelled and described in Chapter 5 were simulated to provide reference output for all aspects of the farm. Table 5.1 shows important summary statistics for the representative farm that will be used as comparators across each scenario and sensitivity analysis. Figure 6.1 displays the yearly mean cash flow and confidence intervals over the twenty year time horizon. Complete summary statistics are shown in Table M.1 in Appendix M.

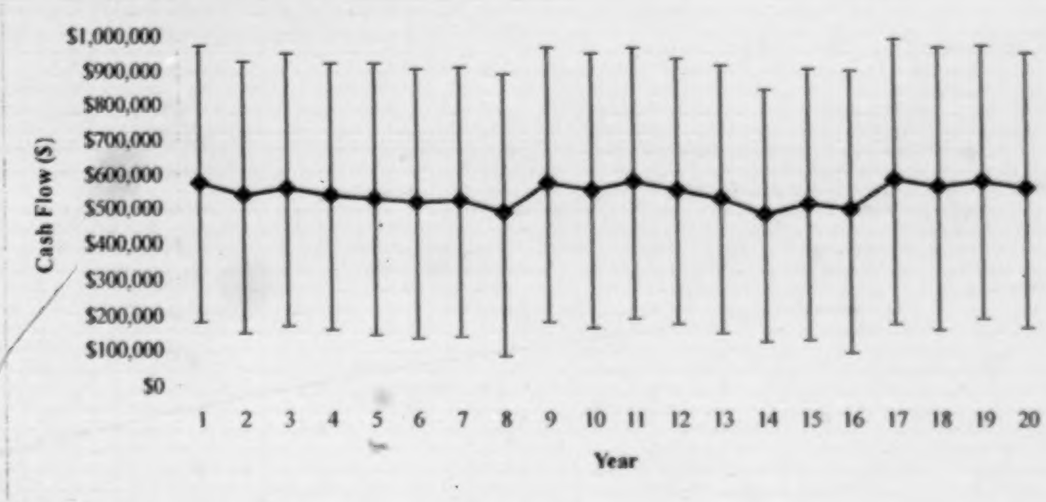
Table 6.1 - Summary statistics for the base simulation scenario of the representative farm

Variable	Mean	Std.Dev.
Twenty Year NPV	$4,607,467	$711,811
NPV with Perpetuity	$5,433,749	$898,903
Crop Enterprise NPV	$3,098,460	$722,466
Beef Enterprise NPV	$1,173,295	$182,402
Forage Sales	$45,333	$6,238
Grazing Season Days	301.53	11.48
Weaning Weight (lbs)	577.52	18.95

NPV results for the scenarios and sensitivity analyses to follow were compared to the base case by subtracting them from the base case NPV results. If BMP implementation improves cash flows and farm returns, then differences will be positive and vice-versa if differences are negative. As seen above, there are four NPV values that can be compared. These are the twenty year NPV and the NPV with perpetuity as well as the NPV estimates for the crop and beef enterprise. The NPV with perpetuity takes into account the expected cash flows that occur beyond the twenty year time horizon established in the simulation. It assumes that the changes to the farm through BMP implementation and any costs/benefits will be present in the long run. The long run analysis past year twenty should increase the NPV and standard deviation as the calculation takes additional years of modified net cash flows and the increased probability of having a very profitable or unprofitable year. Consequently, Table 6.1 shows that the average NPV with perpetuity is greater than the twenty year NPV (17.9%) as is the standard deviation (16.4%).

Average revenues for the farm over the twenty year period equalled approximately one million dollars putting this farm in the top 15% of farms in terms of gross farm receipts (Table 3.2). The modified net cash flows shown in Figure 6.1 and the size of the NPV estimates are realistic of what the other farms in this region generate for revenues. As stated in Chapter 5 (Section 5.5.1, 5.5.2, 5.5.3), the beef and crop enterprise NPVs only include revenues and costs specific to those enterprises and thus do not sum to the twenty year farm NPV. Forage sales are an average of the yearly sale of any hay or silage over the twenty year period and it is clear that the farm is a net seller of forage which was to be expected with their land base and farm structure in southern Alberta. Weaning weights and grazing season days are annual means over the twenty year period. On average, the farm weans and sells calves at weights over the desired market weight of 550 pounds.

Figure 6.1 – Modified net cash flow for the representative farm over the 20 year time horizon with 95% confidence intervals



6.1.2 Cropland BMPs

The following sections discuss results pertaining to BMPs implemented on cropland. Table 6.2 displays the acreage protected at each protection level. This table also provides information concerning the capital cost of fencing for acreage returned to riparian habitat in the BMPs that utilize riparian fencing.

Table 6.2 - Summary of acreage protected and/or converted with BMP #1 and #2 implementation and subsequent fencing and maintenance costs

	Riparian Protection Level			
	25%	50%	75%	100%
Crop and Silage Acreage Lost	38.7	77.4	116.1	154.9
Acreage Returned to Riparian Habitat	17.6	35.2	52.8	70.4
Acreage Converted to Permanent Cover	21.1	42.2	63.4	84.5
Capital Cost of Fencing	$15,783	$31,565.0	$47,348.6	$63,130.0
Yearly Maintenance Cost	$315.7	$631.3	$946.9	$1,262.6

At the lowest and highest riparian protection level, 38.7 and 154.9 total acres were taken out of crop production, respectively, and converted to a combination of riparian habitat and permanent cover. This conversion is weighted between all land use types including crop and forage land. Acreage that is used for hay production is included in this calculation. Essentially, this acreage that is converted to permanent cover still produces the same hay as before. The acreage that is allocated to riparian habitat is taken totally out of production. In BMP #1 and BMP #2, 17.6 and 70.4 acres were returned to riparian habitat and the remaining 21.12 and 84.48 acres were converted to permanent cover for hay production at the lowest and highest protection level, respectively. With the implementation of BMP #3, all crop and silage acreage is converted to buffer strips. BMP #2 and #3 utilize fencing and these costs are represented in Table 6.2. At each protection level for cropland BMP #1 and #2, approximately 45% of the total converted acreage was assumed to be riparian habitat and the remaining 55% was converted to permanent cover or buffer strips[26]. For BMP #3, the complete acreage taken away from crop production is converted to riparian acreage.

6.1.2.1 BMP #1: Conversion of Cropland with Aftermath Grazing to Permanent Cover

In this scenario, cropland was returned to riparian habitat and converted to permanent cover (Figure 5.3). This scenario was performed over the four riparian protection levels and compared to the base farm. Complete statistics and results for this scenario are found in Table M.2 in Appendix M.

For all riparian protection levels, the conversion proved to be costly to the producer (Table 6.3). The twenty year NPV of the farm decreased in each case, ranging from a $14,591 decrease at the 25% protection level to a $53,055 decrease at the 100% protection level. On a per acre of cropland converted basis, the average decrease in NPV over the protection levels is $355.00.

At the 25% protection level, the annualized NPV decrease per acre or the equivalent annual cost (EAC) per acre [27] is calculated to be $44.26. At the 100% protection level, the annualized NPV decrease per acre is calculated to be $40.24. This decrease in NPV can be viewed as the opportunity cost of converting cropland to the respective riparian habitat and permanent cover acreages under the assumptions and model framework of this study. With the same number of acres converted, if the riparian habitat acreage increased at the expense of permanent cover acreage, then the producer can expect a larger annualized opportunity cost per acre and vice versa if the riparian habitat acreage decreased.

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[26] These values are approximations, actual percentages are 45.45% and 54.554%.

[27] Annuities and EAC are explained in Section 5.3.3.

Table 6.3 - Comparison of summary statistics for BMP #1 at different riparian protection levels with the base case

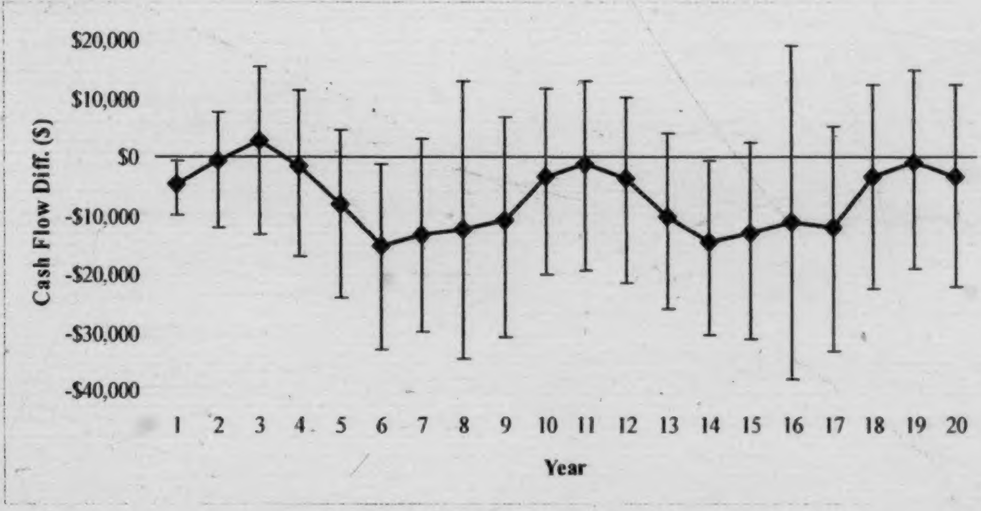
		Riparian Protection Level			
	Base	25%	50%	75%	100%
Farm NPV Mean	$ 4,607,467	$ 4,592,876	$ 4,580,048	$ 4,567,213	$ 4,554,412
St. Dev.	$ 771,811	$ 769,559	$ 763,814	$ 758,154	$ 752,541
Total NPV Reduction		$ 14,590.70	$ 27,418.53	$ 40,253.79	$ 53,054.98
NPV Reduction ($/ac Converted)		$ 376.83	$ 354.06	$ 346.54	$ 342.56
Annualized Reduction ($/ac Converted)		$ 44.26	$ 41.59	$ 40.70	$ 40.24
Annual Forage Sales Mean	$ 45,333	$ 47,619	$ 48,799	$ 49,980	$ 51,161
St. Dev.	$ 6,328	$ 6,448	$ 6,440	$ 6,434	$ 6,430
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,088,144	$ 3,075,083	$ 3,062,050	$ 3,049,043
St. Dev.	$ 722,466	$ 719,655	$ 713,549	$ 707,466	$ 701,398
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,170,145	$ 1,170,950	$ 1,171,690	$ 1,172,404
St. Dev.	$ 182,402	$ 182,527	$ 182,472	$ 182,464	$ 182,472
Grazing Season Days	301.5	301.5	301.5	301.5	301.5
Weaning Weight (lbs)	577.5	577.5	577.5	577.5	577.5

At the enterprise level, the results are consistent with what would be expected with this land conversion. Within the crop enterprise (Table 6.3), NPV over the twenty year period decreased due to the reduction in cropland acreage with BMP implementation. The increase in forage sales is not sufficient to offset the decrease in crop enterprise cash flows. With each increase in the protection level, the amount of hay that is produced on a yearly basis increases leading to larger inventory sell-offs. The representative farm studied is thus a net seller of silage and hay but overall crop enterprise NPV decreased as the protection level increased.

The reason for the decrease in the NPV for the beef enterprise is the same as that of the crop enterprise (Table 6.3). Silage acreage is included in the land base that is converted to riparian habitat and permanent cover. In cases where silage supply does not meet livestock demand, the cost to buy silage increases. This does not, however, explain the small increase in beef enterprise NPV as the riparian protection level increases. Due to the increased hay acreage and subsequent hay production at each level of protection, the frequency with which on-farm supply of hay is insufficient to meet the demand of the beef herd is reduced, with corresponding decreases in the amount of hay that must be purchased. This essentially reduces the cost per head of feeding hay during the winter. Furthermore, with the reduction of silage acreage and thus yield, the holding cost of silage is reduced on an annual basis. Figure 6.2 shows this phenomenon where the cash flows in some years with BMP implementation are greater than for the base case.

The averages and confidence intervals of the non-discounted cash flows in Figure 6.2 show large standard deviations around the difference in cash flows between the base and this scenario. Except for years 6 and 14, the difference between the two cash flows does not seem to be statistically different from zero over 1000 iterations.

Figure 6.2 - Difference in cash flows at the 100% protection level between BMP #1 and the base case



The large confidence intervals around the net cash flows in years 8 and 16 are due to possibility of large forage sales that may occur as inventory levels rise. In each case, the forage rotation ends in the previous year (i.e., years 7 and 15) (Table 5.2) and dependant on growing conditions in the previous years it is more likely that either a larger inventory sale is made or else a larger purchase may be made in these two years.

The differences in the cash flows between the two scenarios result in the differences in the NPVs that are being compared. Thus, understanding the statistical significance of the differences in cash flows will clarify if the differences in the means can be treated as statistically significant. For example, in Table 6.3, there are large differences in the means of the NPVs at each protection level. However, Figure 6.2 shows that only three of the twenty years differences in cash flows between BMP #1 and the base are statistically different from zero at the 100% protection level. The simulation of 1000 iterations and the distributions around the stochastic variables tell us that it is possible to have no economic difference in the outcome of a decision to convert cropland to permanent cover even though the NPV means are different. This is important for the producer in deciding whether it is in their best interest to implement the BMP. It is also important to the policymaker in deciding whether subsidization is needed or justified in convincing the producer to implement a BMP.

A comparison of the change in NPV with perpetuity was also performed. Table 6.4 compares the NPV differences between the twenty year NPV and NPV with perpetuity. The NPV value increases approximately 17.9% from the twenty year NPV to the NPV with perpetuity in step with a 16.4% increase in standard deviations over the base case and each protection level. The comparisons of the NPV reduction, NPV reduction per acre and annualized reduction per acre with each NPV estimation shows a small difference. Using the NPV with perpetuity seems to make the reduction per acre less variable across protection levels to a constant dollar value at approximately $45.50. The ability to place a constant dollar value on the conversion of any acreage is convenient for cost derivation for the producer or policy maker when deciding what acreage to convert. The results for the rest of the section will include results using both NPV estimations.

Table 6.4 - Comparison of results for BMP #1 using the twenty year NPV estimation and the NPV with perpetuity estimation

	Riparian Protection Level				
	Base	25%	50%	75%	100%
Crop & Silage Acreage Lost		38.72	77.44	116.16	154.88
Twenty Year NPV	$ 4,607,467	$4,592,876	$4,580,048	$4,567,213	$4,554,412
St. Dev.	$ 771,811	$ 769,559	$ 763,814	$ 758,154	$ 752,541
NPV with Perpetuity	$ 5,433,750	$5,418,658	$5,404,273	$5,389,892	$5,375,565
St. Dev.	$ 898,902	$ 896,055	$ 889,100	$ 882,235	$ 875,411
Total NPV Reduction					
Twenty Year NPV		$ 14,591	$ 27,419	$ 40,254	$ 53,055
NPV with Perpetuity		$ 15,092	$ 29,477	$ 43,858	$ 58,185
NPV reduction/acre					
Twenty Year NPV		$ 376.83	$ 354.06	$ 346.54	$ 342.56
NPV with Perpetuity		$ 389.77	$ 380.64	$ 377.57	$ 375.68
Annualized Reduction/acre					
Twenty Year NPV		$ 44.26	$ 41.59	$ 40.70	$ 40.24
NPV with Perpetuity		$ 45.78	$ 44.71	$ 44.35	$ 44.13

Note: The model was not formulated to estimate distributions around the means of the NPV with perpetuity so these estimates will not be presented further in this study.

6.1.2.2 BMP #2: Conversion of Cropland with Aftermath Grazing to Permanent Cover with Temporary Access Fencing

This scenario (BMP #2) is similar to the BMP #1. However, fencing is added to the management option to withhold livestock from entering riparian areas (Figure 5.4). The complete summary of results is found in Table M.3 in Appendix M.

As seen in Table 6.5, acreage conversion and the trend in NPV over the protection levels is the same as for BMP #1. The larger decrease in total NPV, the total cost per acre converted and annualized decrease in NPV per acre is due to the significant cost of fencing riparian areas at each protection level. On an annual basis, the cost to fence one acre of land is the difference in the annualized reductions in NPV between BMP#1 and BMP#2 which is $29.90 per acre using the twenty year NPV or $30.81 per acre in perpetuity, or approximately $30. The trends in crop enterprise NPV, beef enterprise NPV and forage sales are identical to BMP #1. Grazing season length and calf weights off grazing are also identical to BMP #1, as expected. Besides the first three years of cash flows where fencing is established and costs are significant, the cash flows follow the same general trend and cash flow differences do not seem to be significantly different from zero (Figure 6.3).

The significance of this scenario is the opportunity for producers to exercise management expertise to restrict cattle from accessing riparian areas during times of increased riparian sensitivity. With proper education and training, farm managers can use discretion and utilize the rich forage that is available in riparian areas in timely periods while minimizing the impact of livestock on riparian habitats and water. As mentioned in Chapter 5, late season grazing of aftermath and riparian forage may not be as destructive as early season grazing but the possibility of water contamination is still very prevalent. Calculating the benefits of this BMP to the environment and society, economically and/or biologically, from better water quality is not an objective of this study. However, understanding the cost to producers of implementation of this BMP is the first step in a cost/benefit analysis of the best management practice implementation.

Figure 6.3 - Difference in cash flows at the 100% protection level between BMP #2 and the base case

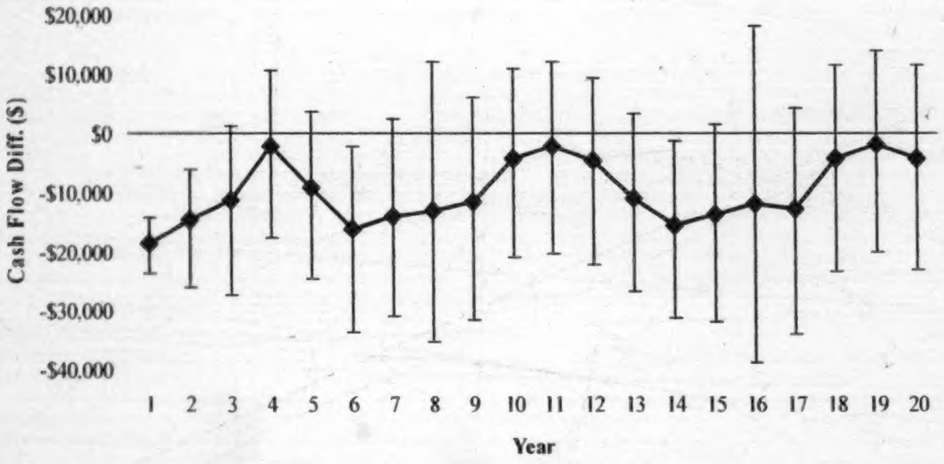


Table 6.5 - Comparison of summary statistics for BMP #2 at different riparian protection levels with the base case

		Riparian Protection Level			
	Base	25%	50%	75%	100%
Twenty Year NPV Mean	$ 4,607,467	$ 4,583,017	$ 4,560,331	$ 4,537,637	$ 4,514,978
St. Dev.	$ 771,811	$ 769,559	$ 763,814	$ 758,154	$ 752,541
NPV with Perpetuity	$ 5,433,750	$ 5,408,501	$ 5,383,959	$ 5,359,421	$ 5,334,936
Total NPV Reduction					
Twenty Year NPV Mean		$ 24,449.23	$ 47,135.60	$ 69,829.40	$ 92,489.12
NPV with Perpertiuty		$ 25,249.43	$ 49,791.44	$ 74,329.44	$ 98,813.55
NPV Reduction/Acre					
Twenty Year NPV Mean		$ 631.44	$ 608.67	$ 601.15	$ 597.17
NPV with Perpertiuty		$ 652.10	$ 642.97	$ 639.89	$ 638.00
Annualized Reduction /acre					
Twenty Year NPV Mean		$ 74.17	$ 71.49	$ 70.61	$ 70.14
NPV with Perpertiuty		$ 76.60	$ 75.52	$ 75.16	$ 74.94
Annual Forage Sales Mean	$ 45,333	$ 47,619	$ 48,799	$ 49,980	$ 51,161
St. Dev.	$ 6,328	$ 6,448	$ 6,440	$ 6,434	$ 6,430
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,088,144	$ 3,075,083	$ 3,062,050	$ 3,049,043
St. Dev.	$ 722,466	$ 719,655	$ 713,549	$ 707,466	$ 701,398
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,170,145	$ 1,170,950	$ 1,171,690	$ 1,172,404
St. Dev.	$ 182,402	$ 182,527	$ 182,472	$ 182,464	$ 182,472
Grazing Season Days	301.5	301.5	301.5	301.5	301.5
Weaning Weight (lbs)	577.5	577.5	577.5	577.5	577.5

6.1.2.3 BMP #3: Conversion of Cropland with Aftermath Grazing to Buffer Strips with Cattle Exclusion

This scenario is the most protectionist of all cropland BMPs. Cropland is converted to buffer strips where no agricultural production takes place. Cattle are completely removed from riparian grazing (Figure 5.5). Complete statistics and results for this scenario are found in Table M.4 in Appendix M.

The same acreage is converted out of crop production as for BMP #1 and #2, except that all acreage is now converted to riparian habitat. Table 6.6 shows the results at each protection level. At each level, the conversion proves to be costly to producers and differences in cash flows are statistically different from zero (Figure 6.4). The maximum decrease in NPV is $200,121 at the 100% protection level, and the minimum decrease is

$48,125 at the 25% protection level. In perpetuity, these costs rise to $237,198 and $57,389 respectively. This is equivalent to an annualized decrease per acre at the 100% and 25% protection level of $151.77 and $145.99, respectively, or $179.89 and $174.10 in perpetuity. The complete exclusion of cattle from riparian areas decreases the grazing season length and thus weaning weights. These weights are still above the desired market weight of 550 pounds but nonetheless result in decreased beef enterprise revenues compared to the base scenario. The crop enterprise NPV and forage sales decrease over the protection levels as more land is removed from production.

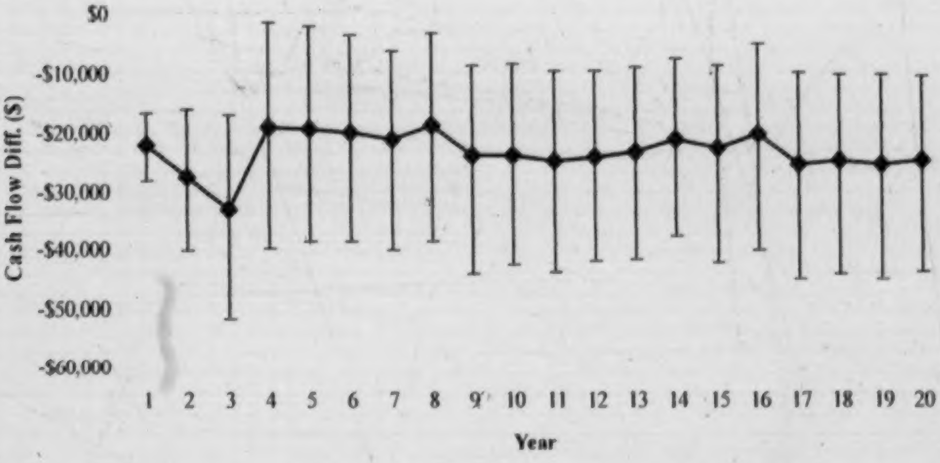
Table 6.6 - Comparison of summary statistics of BMP #3 at different riparian protection levels with the base case

		Riparian Protection Level			
	Base	25%	50%	75%	100%
Twenty Year NPV Mean	$ 4,607,467	$ 4,559,341	$ 4,508,739	$ 4,457,935	$ 4,407,345
St. Dev.	$ 771,811	$ 765,427	$ 759,258	$ 752,800	$ 746,596
NPV with Perpetuity	$ 5,433,750	$ 5,376,360	$ 5,316,492	$ 5,256,395	$ 5,196,552
Total NPV Reduction					
Twenty Year NPV Mean		$ 48,125.42	$ 98,728.17	$ 149,531.59	$ 200,121.27
NPV with Perpertiuty		$ 57,389.98	$ 117,258.08	$ 177,355.33	$ 237,198.06
NPV Reduction/Acre					
Twenty Year NPV Mean		$ 1,242.91	$ 1,274.90	$ 1,287.29	$ 1,292.11
NPV with Perpertiuty		$ 1,482.18	$ 1,514.18	$ 1,526.82	$ 1,531.50
Annualized Reduction /acre					
Twenty Year NPV Mean		$ 145.99	$ 149.75	$ 151.20	$ 151.77
NPV with Perpertiuty		$ 174.10	$ 177.85	$ 179.34	$ 179.89
Annual Forage Sales Mean	$ 45,333	$ 44,684	$ 44,022	$ 43,361	$ 42,699
St. Dev.	$ 6,328	$ 6,261	$ 6,193	$ 6,126	$ 6,058
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,058,641	$ 3,017,900	$ 2,977,174	$ 2,936,455
St. Dev.	$ 722,466	$ 715,624	$ 708,761	$ 701,901	$ 695,033
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,748	$ 1,172,776	$ 1,171,551	$ 1,170,497
St. Dev.	$ 182,402	$ 182,503	$ 182,571	$ 182,790	$ 182,945
Grazing Season Days	301.5	301.3	300.9	300.5	300.1
Weaning Weight (lbs)	577.5	577.1	576.5	575.9	575.2

As with BMP #1 and BMP #2, the crop enterprise NPV for BMP #3 still trends downward with increased protection levels. However, relative to the first two BMPs the magnitude is greater because of the complete loss of all acreage. In the previous BMPs, revenue was still generated from 55% of the acreage removed from crop production in the form of hay.

With respect to the beef enterprise, the trend in BMP #3 is opposite from that of BMP #1 and #2. The NPV of the beef enterprise decreases as the protection level increases whereas in BMP #1 and #2 the opposite is true. The reason for this difference lies in the modelling of forage rotations, specifically hay. The incorporation of stochastic hay yields as well as the hay yield response to the year of the stand makes the loss of hay production very costly. The complete loss of hay production proves to be costly to the beef enterprise as the feeding cost per head increases as the protection level increases. The loss of hay acreage may become even more costly if there is no available supply to be bought. This study assumes that hay is readily available for purchase but in reality, years of drought or a crisis such as BSE may limit the availability of hay or increase the price.

Figure 6.4 - Difference in cash flow at the 100% protection level between BMP #3 and the base case



6.1.3 Pasture Land BMPs

The following sections provide a discussion for the results of BMP implementation on pasture land. Initially, it is assumed that there are no productivity gains associated with adoption of these BMPs and therefore the analysis mainly portrays the cost to the producer of implementation. Later, the sensitivity of these results to potential productivity gains is examined. Table 6.8 shows the acreage protected at each protection level along with the capital cost of off-stream watering site development, fencing and the maintenance costs. There is no permanent cover conversion on pastureland. Due to the large land base attributed to grazing pasture, the acreage that is to be protected is much larger than acreage protected on crop and forage land.

Table 6.7 - Summary of acreage protected due to BMP implementation and subsequent capital and maintenance costs

	Riparian Protection Level			
	25%	50%	75%	100%
Grazing Acreage Protected	63.2	126.4	189.6	252.8
Off-Stream Watering Cost	$30,420.8	$30,420.8	$30,420.8	$30,420.8
Yearly Maintenance Cost	$608.4	$608.4	$608.4	$608.4
Fencing Cost	$56,673.6	$113,347.2	$170,020.8	$226,694.4
Yearly Maintenance Cost	$1,133.5	2,266.9	$3,400.4	4,553.9

The pasture land protected at each level in Table 6.8 should be compared to the acreage returned to riparian habitat in Table 6.2 for a complete understanding of the large acreage and riparian protection difference between crop and pasture land. Riparian areas in pasture land are protected by fencing which is the case in BMP #5 and #6. With BMP #4, there is no riparian protection. Off-stream watering locations are established at a cost shown above.

6.1.3.1 BMP #4: Off-Stream Watering

This is the first BMP option for the beef enterprise of the farm. Off-stream watering sites are established, but there are no other changes. Full summary statistics are displayed in Table M.5 in Appendix M.

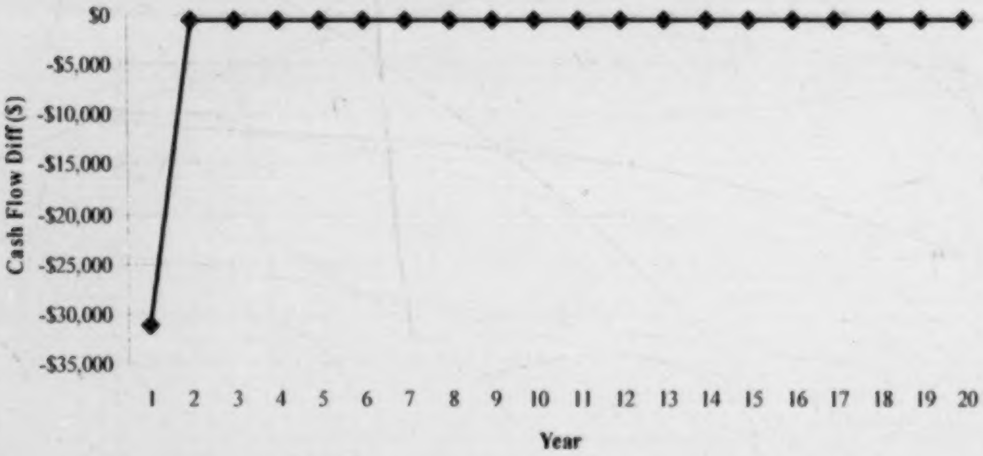
As suggested by the literature outlined in section 2.4.1, this BMP involves establishing an off-stream watering site in upland areas in an effort to draw livestock away from riparian areas and natural sources of drinking water. Table 6.9 shows the cost to the producer of establishing off-stream watering sites. All summary statistics with BMP implementation are the same as that of the base case with the exception of the twenty year NPV and the NPV with perpetuity, which are both lower than those for the base scenario. This result occurs because of the costs of off-stream watering sites as well as the annual maintenance costs. All other relationships and farm dynamics remain the same.

The differences in cash flows over twenty years between the base case and this BMP are significantly different from zero due to the costs of implementing and maintaining off-stream watering sites (Figure 6.5). There are no confidence intervals placed around the means as the difference in cash flow is strictly due to the costs of capital and maintenance, which are non-stochastic.

Table 6.8 - Comparison of summary statistics of BMP #4 with the base case

	Base	BMP #4
Farm NPV Mean	$ 4,607,467	$ 4,574,633
St. Dev.	$ 771,811	$ 771,811
NPV with Perpertiuty	$ 5,433,750	$ 5,400,011
Total NPV Reduction		
Twenty Year NPV		$ 32,834.02
NPV with Perpertiuty		$ 33,738.54
Annual Forage Sales Mean	$ 45,333	$ 45,333
St. Dev	$ 6,328	$ 6,328
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,098,460
St. Dev	$ 722,466	$ 722,466
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,295
St. Dev	$ 182,402	$ 182,402
Grazing Season Days	301.5	301.5
Weaning Weight (lbs)	577.5	577.5

Figure 6.5 - Difference in cash flow between BMP #4 and the base case



6.1.3.2 BMP #5: Off-Stream Watering with Temporary Access Fencing

As discussed in section 5.4.3.2, this BMP establishes off-stream watering sites for livestock as well as fencing along riparian areas to protect acreage from access by cattle. Summary statistics for each protection level are provided in Table I.6 in Appendix I.

Table 6.10 shows the decrease in NPV with the implementation of this BMP at different riparian protection levels. It is clear that there are significant costs in implementing this BMP, mainly due to the cost of fencing. At the 25% protection level which protects 63.2 acres of grazing pasture, the NPV decrease equals $88,464 and $91,054 using the twenty year NPV or the NPV with perpetuity, respectively. On an annualized cost per acre basis, that equates to $164.41 and $169.23 per acre, respectively. At the 100% protection level, the NPV decrease equals $255,355 or $262,999 with the twenty year NPV or NPV with perpetuity, respectively. A $118.65 or $122.20 decrease per acre is realized on an annualized basis using the twenty year or perpetuity. Notice that the standard deviation does not change across protection levels. This is a result of the assumption made that livestock are still able to utilize all riparian grazing potential discussed in section 5.4.3.2. The reason why NPV decreased compared to the base was the fencing and off-stream watering implementation and maintenance costs. There was no impact on grazing season days which can impact other aspects of the model including winter feed costs and calf market selling weights leading to changes in the NPV through time. The capital costs simply add an expense to the modified net cash flow but do not impact bio-physical relationships in this case.

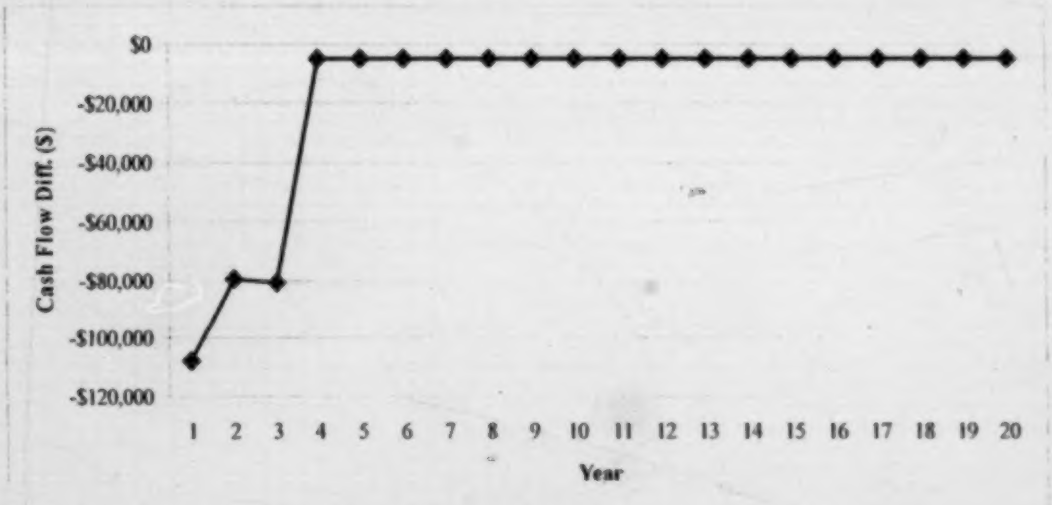
The annualized cost per acre decreases from the 25% to the 100% protection level due to the amount of acres that are being protected at each level and the cost of off-stream watering. The cost per head of off-stream watering sites does not change with the riparian protection level and the cost of fencing. Therefore, as the protected acreage increases, the cost of off-stream watering allocated per acre decreases. From a strict cost comparison, it may not be a viable solution to implement this BMP (Platts and Wagstaff, 1984) without considering any potential benefits from cow/calf productivity gains (section 6.2) or the public benefits to having healthier riparian areas and cleaner water. Productivity gains are considered in the sensitivity analysis provided later in this chapter. The effect of public benefits is beyond the scope of the current study. The difference in cash flows between the base and this BMP are significantly different from zero for the same reasons as the previous section (Figure 6.6).

This BMP allows managers to be a key contributor to preserving riparian health and water quality. The temporary access fencing gives the producer the ability to control livestock access to riparian areas and water. The producer is able to deny livestock access to riparian areas in early spring after the spring run-off when soil is most sensitive to trampling and compaction or after a heavy rainfall (Section 5.4.3.2). The grazing season days and calf weights off grazing are equal to the base because it is assumed that the producer allows access to riparian vegetation but in a controlled environment. The cattle do not overgraze and degrade the environment like would otherwise occur in an uncontrolled grazing strategy (Kaufmann and Kreuger, 1984; Platts, 1979)

Table 6.9 - Comparison of summary statistics for BMP #5 at different riparian protection levels with the base case

	Riparian Protection Level				
	Base	25%	50%	75%	100%
Farm NPV Mean	$ 4,607,467	$ 4,519,002	$ 4,463,372	$ 4,407,742	$ 4,352,111
St. Dev.	$ 771,811	$ 771,811	$ 771,811	$ 771,811	$ 771,811
NPV with Perpertiuty	$ 5,433,750	$ 5,342,696	$ 5,285,381	$ 5,228,066	$ 5,170,751
Total NPV Reduction					
Twenty Year NPV Mean		$ 88,464.33	$ 144,094.64	$ 199,724.95	$ 255,355.26
NPV with Perpertiuty		$ 91,053.69	$ 148,368.83	$ 205,683.97	$ 262,999.11
NPV Reduction/Acre					
Twenty Year NPV Mean		$ 1,399.75	$ 1,139.99	$ 1,053.40	$ 1,010.11
NPV with Perpertiuty		$ 1,440.72	$ 1,173.80	$ 1,084.83	$ 1,040.34
Annualized Reduction /acre					
Twenty Year NPV Mean		$ 164.41	$ 133.90	$ 123.73	$ 118.65
NPV with Perpertiuty		$ 169.23	$ 137.87	$ 127.42	$ 122.20
Annual Forage Sales Mean	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333
St. Dev	$ 6,328	$ 6,328	$ 6,328	$ 6,328	$ 6,328
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460
St. Dev	$ 722,466	$ 722,466	$ 722,466	$ 722,466	$ 722,466
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,295	$ 1,173,295	$ 1,173,295	$ 1,173,295
St. Dev	$ 182,402	$ 182,402	$ 182,402	$ 182,402	$ 182,402
Grazing Season Days	301.5	301.5	301.5	301.5	301.5
Weaning Weight (lbs)	577.5	577.5	577.5	577.5	577.5

Figure 6.6 - Difference in cash flows at the 100% protection level between BMP #5 and the base case



6.1.3.3 BMP #6: Off-Stream Watering with Cattle Exclusion

Similar to BMP #3 for cropland, this is the most protectionist of all pasture land BMPs. Livestock are completely excluded from riparian environments at all times of the year (Figure 5.6). Complete summary statistic for this BMP scenario can be found in Table M.7 in Appendix M.

The cost of this BMP is over and above that of BMP #5 due to the complete loss of grazing acreage that occurs with the fencing and protection of riparian acreage. The total reduction in NPV at the 25% and 100% protection levels is $104,703 and $320,793, respectively, using the twenty year NPV. The NPV with perpetuity is reduced by $110,858 and $342,042 at the 25% and 100% protection levels, respectively. The annualized reduction in NPV per acre protected at the 25% and 100% protection levels is $194.59 and $148.77, respectively, using the twenty year NPV and $206.03 and $158.92, respectively, using the NPV with perpetuity (Table 6.11). In perpetuity, these costs are higher as the BMP implementation continues to have an impact beyond year twenty. The difference in cash flows from the base over the twenty year period is significantly different from zero (Figure 6.7). With the decrease in grazing season days at different protection levels, forage sales decrease as more feed is needed to winter the herds. This reduces crop enterprise NPV as well as beef enterprise NPV as weaning weights are lower, although still above the desired market weight of 550 lbs.

Figure 6.7 - Difference in cash flow at the 100% protection level between BMP #6 and the base case

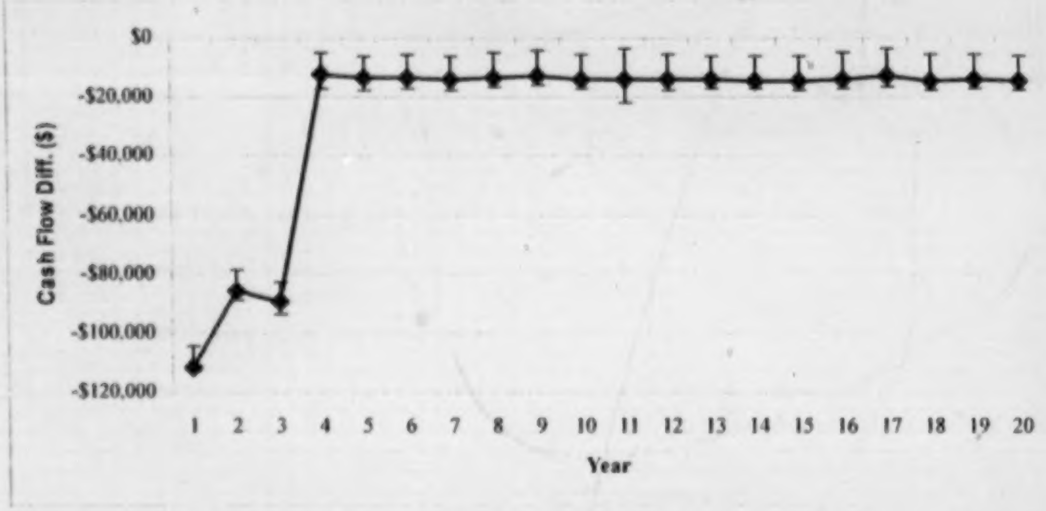


Table 6.10 - Comparison of summary statistics for BMP #6 at different riparian protection levels with the base case

		Riparian Protection Level			
	Base	25%	50%	75%	100%
Farm NPV Mean	$ 4,607,467	$ 4,502,764	$ 4,430,717	$ 4,358,869	$ 4,287,273
St. Dev.	$ 771,811	$ 771,807	$ 771,354	$ 771,017	$ 770,676
NPV with Perpertiuty	$ 5,433,750	$ 5,322,892	$ 5,245,620	$ 5,168,521	$ 5,091,708
Total NPV Reduction					
Twenty Year NPV Mean		$ 104,702.98	$ 176,750.16	$ 248,598.10	$ 320,193.27
NPV with Perpertiuty		$ 110,858	$ 188,130	$ 265,229	$ 342,042
NPV Reduction/Acre					
Twenty Year NPV Mean		$ 1,656.69	$ 1,398.34	$ 1,311.17	$ 1,266.59
NPV with Perpertiuty		$ 1,754	$ 1,488	$ 1,399	$ 1,353
Annualized Reduction /acre					
Twenty Year NPV Mean		$ 194.59	$ 164.25	$ 154.01	$ 148.77
NPV with Perpertiuty		$ 206.03	$ 174.82	$ 164.31	$ 158.92
Annual Forage Sales Mean	$ 45,333	$ 44,999	$ 44,661	$ 44,320	$ 43,975
St. Dev	$ 6,328	$ 6,314	$ 6,301	$ 6,288	$ 6,276
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,089,910	$ 3,081,273	$ 3,072,557	$ 3,063,754
St. Dev	$ 722,466	$ 722,148	$ 721,893	$ 721,662	$ 721,488
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,164,266	$ 1,155,196	$ 1,146,397	$ 1,137,950
St. Dev	$ 182,402	$ 182,670	$ 182,532	$ 181,974	$ 181,373
Grazing Season Days	301.5	299.8	298.1	296.4	294.7
Weaning Weight (lbs)	577.5	574.7	571.9	569.0	566.2

6.2 Sensitivity Analysis

The following sections provide results from simulation analysis that incorporate the possibility of productivity gains from supplying cattle with off-stream watering sites and drawing them away from riparian areas. These productivity gains apply to pasture land BMPs. Furthermore, sensitivity analysis for the discount rate is also conducted.

The productivity gains considered here include calf weight increases off pasture and pasture utilization increases by the herd. Sensitivity analysis of calf weight gains were performed for 1%, 2%, 3%, 5% and 10% increases in daily weight gain over the grazing season. Sensitivity analysis for increased pasture utilization is performed for increases of 1% and 2% per year for three years, for a total pasture utilization increase of 3% and 6%, respectively. Results of the sensitivity analysis are assessed using the 25% and 100% protection levels in order to compare the extremes in riparian protection. It is assumed that results for the 50% and 75% protection levels would lie in between the two extremes. These results are compared to the base case as well as to the respective BMP with no productivity gains.

6.2.1 Calf Weaning Weight Increases

6.2.1.1 BMP #4: Off-Stream Watering

Table 6.13 provides a summary of the results of simulating BMP #4, varying the increase in daily calf weight gain resulting from cattle being provided cleaner drinking water. A complete summary of results for this sensitivity analysis is shown in Table M.8 in Appendix M.

The basis for the sensitivity is to determine the percentage daily weight gain increase market calves would have to achieve to recoup the capital and maintenance costs for the BMP. In this case, the investment is for the off-stream watering sites. It is clear that the calves will have to come off pasture gaining 3% more per day over the average grazing season to recoup the initial investment (Table 6.13).

From the 2% to 3% level of increase, the difference in perpetuity NPV between the base and the BMP scenarios goes from being negative to positive. A daily 3% increase in weight gain leads to an overall weaning weight increase of approximately 2.6% over an average grazing season of 302 days. A 3% daily weight gains increase does not lead to 3% increase in the overall weaning weight because calves are born at an assumed weight of 80 pounds and the percentage weight gain is applied to the daily calf weight gain of the calf, not to the overall weaning weight in the base case. At a weight increase above 3%, the NPV of the farm with BMP implementation is greater than that of the base case. In perpetuity, daily weight gains would need to increase above 2% to recoup the investment or a 1.7% increase in weaning weight over an average grazing season.

However, the 3% increase does not lead to statistically significant increases in cash flows past year 2 once off-stream watering has been established. Figure 6.8 shows the cash flow differences at the 5% daily weight gain increase. A daily weight gain increase above 5% is needed for differences in cash flow to be statistically significant.

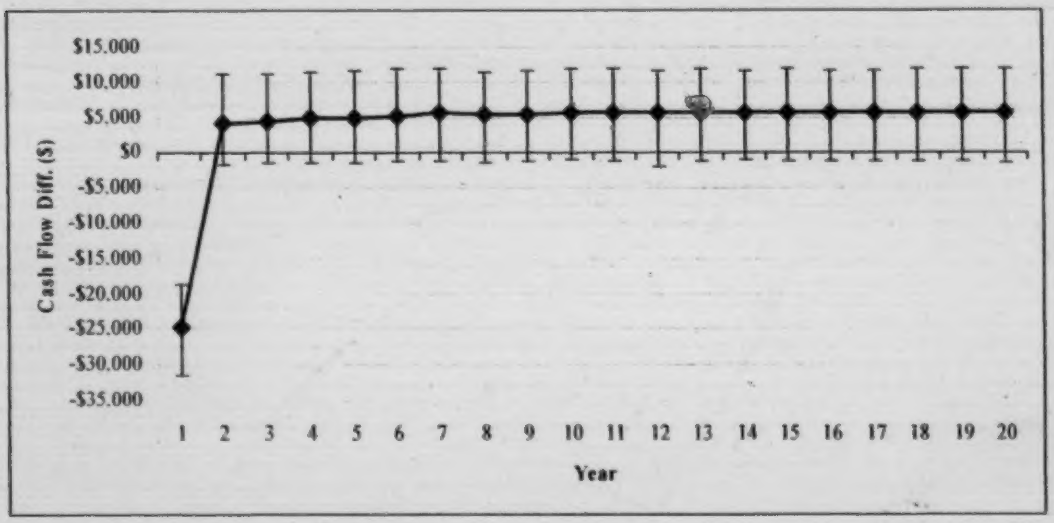
It should be noted that, relative to the base case and the case with no productivity gains, there is only a change in the farm NPV mean, beef enterprise NPV and the calf weaning weight (Table 6.13). Beef enterprise NPV increases in step with the increase in calf weaning weight which increases both the twenty year NPV and NPV with perpetuity. The rest of the results stay the same as for the original BMP scenario, as is expected.

Table 6.11 - Comparison of summary statistics for BMP #4 at different daily weight gain increases of grazing calves

			Daily Weight Gain Increase of Grazing Calves				
	Farm Base	No Prod. Gain	1%	2%	3%	5%	10%
Farm NPV Mean	$ 4,607,467	$ 4,574,633	$ 4,585,216	$ 4,595,289	$ 4,605.896	$ 4,624,491	$ 4.666.818
St. Dev.	$ 771.811	$ 771.811	$ 769,473	$ 766,555	$ 765,325	$ 762,464	$ 769,195
NPV with Perpertiuty	$ 5,433.750	$ 5,400,011	$ 5,412,670	$ 5,424,647	$ 5,437,264	$ 5,459,357	$ 5,509.553
Total NPV Change							
Twenty Year NPV		$ (32.834)	$ (22,251)	$ (12,178)	$ (1,570)	$ 17,024	$ 59.352
NPV with Perpetuity		$ (33,739)	$ (21,080)	$ (9,103)	$ 3.514	$ 25,607	$ 75,803
Annual Forage Sales Mean	$ 45.333	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333
St. Dev	$ 6,328	$ 6,328	$ 6,328	$ 6,328	$ 6,328	$ 6,328	$ 6.328
Crop Enterprise NPV Mean	$ 3.098.460	$ 3,098,460	$ 3,098,460	$ 3,098.460	$ 3.098.460	$ 3,098,460	$ 3.098.460
St. Dev	$ 722,466	$ 722,466	$ 722,466	$ 722,466	$ 722,466	$ 722,466	$ 722,466
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173.295	$ 1,184,500	$ 1,195,267	$ 1,206,670	$ 1,226,667	$ 1,272,293
St. Dev	$ 182.402	$ 182.402	$ 180,428	$ 177,681	$ 177,401	$ 175,928	$ 180,277
Grazing Season Days	301.5	301.5	301.5	301.5	301.5	301.5	301.5
Weaning Weight (lbs)	577.5	577.5	582.5	587.5	592.4	602.4	627.3

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

Figure 6.8 - Difference in Cash Flows between BMP #4 with a 5% increase in calf weights and the base case



6.2.1.2 BMP #5: Off-Stream Watering with Temporary Access Fencing

Table 6.14 and 6.15 show the simulation results from weaning weight increases at the 100% and 25% protection level, respectively. Tables M.9 and M.10 in Appendix M show complete summary statistics for these simulations.

At the 100% protection level, the capital and maintenance costs of fencing are greater than the potential benefits for weight increases of up to 10% per day (i.e., the maximum productivity increase considered in the analysis). These results are consistent with literature that highlights the high costs to implementing fencing for riparian and water protection (BCMAFF, 2003). The annualized reduction per acre protected is between $71 and $76 with a 10% increase in daily calf weight gains depending on the NPV estimate that is used (Table 6.14) . This BMP still utilizes all grazing capacity in riparian areas but allows producer to use discretion in how and when the grazing is used in an effort to reduce livestock impact on riparian zones. The net result here is that while increased production helps to offset the costs of implementing this BMP with full riparian protection, there is still a significant net cost.

Table 6.12 - Comparison of summary statistics for BMP #5 at the 100% protection level at different daily weight increases of grazing calves

			Daily Weight Gain Increase of Grazing Calves				
	Farm Base	No Prod. Gain	1%	2%	3%	5%	10%
Farm NPV Mean	$4,607,467	$ 4,352,111	$ 4,362,695	$ 4,372,768	$ 4,383,375	$ 4,401,970	$ 4,444,297
St. Dev.	$ 771,811	$ 771,811	$ 769,473	$ 766,555	$ 765,325	$ 762,464	$ 769,195
NPV with Perpertiuty	$ 5,433,750	$ 5,170,751	$ 5,183,409	$ 5,195,386	$ 5,208,004	$ 5,230,097	$ 5,280,293
Total NPV Change							
Twenty Year NPV Mean		$ (255,355)	$ (244,772)	$ (234,699)	$ (224,092)	$ (205,497)	$ (163,170)
NPV with Perpertiuty		$ (262,999)	$ (250,341)	$ (238,364)	$ (225,746)	$ (203,653)	$ (153,457)
NPV Change/Acre							
Twenty Year NPV Mean		$ (1,010.11)	$ (968.24)	$ (928.40)	$ (886.44)	$ (812.88)	$ (645.45)
NPV with Perpertiuty		$ (1,040.34)	$ (990.27)	$ (942.89)	$ (892.98)	$ (805.59)	$ (607.03)
Annualized Change/acre							
Twenty Year NPV Mean		$ (118.65)	$ (113.73)	$ (109.05)	$ (104.12)	$ (95.48)	$ (75.81)
NPV with Perpertiuty		$ (122.20)	$ (116.32)	$ (110.75)	$ (104.89)	$ (94.62)	$ (71.30)
Annual Forage Sales Mean	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333
St. Dev	$ 6,328	$ 6,328	$ 6,328	$ 6,328	$ 6,328	$ 6,328	$ 6,328
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460
St. Dev	$ 722,466	$ 722,466	$ 722,466	$ 722,466	$ 722,466	$ 722,466	$ 722,466
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,295	$ 1,184,500	$ 1,195,267	$ 1,206,670	$ 1,226,667	$ 1,272,293
St. Dev	$ 182,402	$ 182,402	$ 180,428	$ 177,681	$ 177,401	$ 175,928	$ 180,277
Grazing Season Days	301.5	301.5	301.5	301.5	301.5	301.5	301.5
Weaning Weight (lbs)	577.5	577.5	582.5	587.5	592.4	602.4	627.3

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

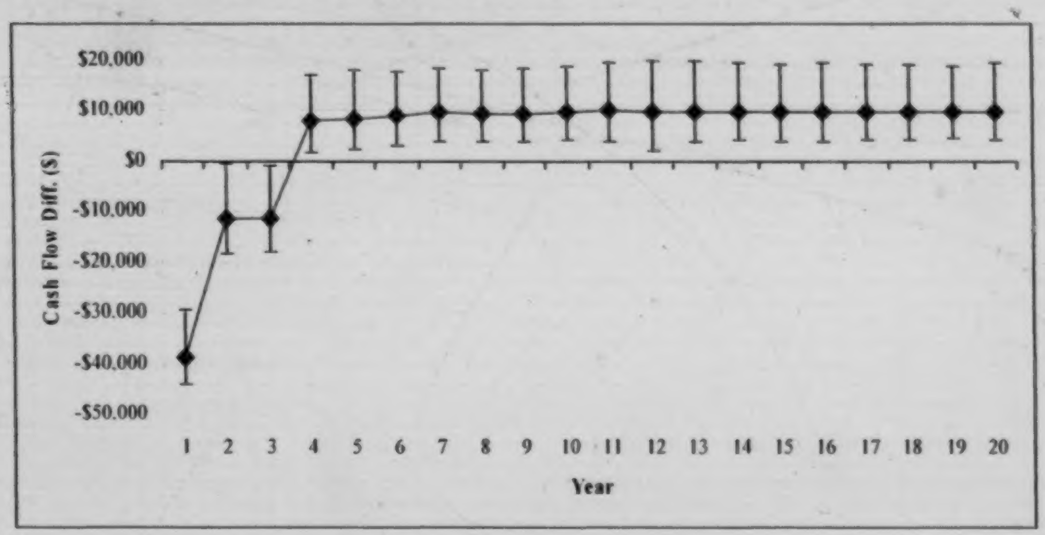
Table 6.13 - Comparison of summary statistics for BMP #5 at the 25% protection level at different daily weight increases of grazing calves

			Daily Weight Gain Increase of Grazing Calves				
	Farm Base	No Prod. Gain	1%	2%	3%	5%	10%
Farm NPV Mean	$4.607.467	$ 4.519.002	$ 4,529.586	$ 4,539,659	$ 4.550,266	$ 4,568.861	$ 4,611.188
St. Dev.	$ 771.811	$ 771.811	$ 769.473	$ 766,555	$ 765.325	$ 762,464	$ 769.195
NPV with Perpertiuty	$5.433.750	$ 5,342.696	$ 5,355,355	$ 5.367,332	$ 5,379.949	$ 5,402,042	$ 5,452,238
Total NPV Change							
Twenty Year NPV Mean		$ (88.464)	$ (77.881)	$ (67.808)	$ (57,201)	$ (38.606)	$ 3.721
NPV with Perpertiuty		$ (91.054)	$ (78,395)	$ (66.418)	$ (53.801)	$ (31.708)	$ 18.488
NPV Change/Acre							
Twenty Year NPV Mean		$ (1.399.75)	$ (1.232.29)	$ (1.072.91)	$ (905.07)	$ (610.85)	$ 58.88
NPV with Perpertiuty		$ (1.440.72)	$ (1.240.43)	$ (1.050.92)	$ (851.28)	$ (501.71)	$ 292.54
Annualized Change/acre							
Twenty Year NPV Mean		$ (164.41)	$ (144.74)	$ (126.02)	$ (106.31)	$ (71.75)	$ 6.92
NPV with Perpertiuty		$ (169.23)	$ (145.70)	$ (123.44)	$ (99.99)	$ (58.93)	$ 34.36
Annual Forage Sales Mean	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333	$ 45,333
St. Dev	$ 6.328	$ 6,328	$ 6.328	$ 6,328	$ 6,328	$ 6.328	$ 6,328
Crop Enterprise NPV Mean	$3,098.460	$ 3,098.460	$ 3,098.460	$ 3,098.460	$ 3,098.460	$ 3,098,460	$ 3,098.460
St. Dev	$ 722.466	$ 722.466	$ 722.466	$ 722.466	$ 722,466	$ 722.466	$ 722,466
Beef Enterprise NPV Mean	$1,173.295	$ 1,173.295	$ 1,184,500	$ 1,195,267	$ 1,206,670	$ 1,226,667	$ 1,272.293
St. Dev	$ 182,402	$ 182,402	$ 180,428	$ 177,681	$ 177,401	$ 175,928	$ 180,277
Grazing Season Days	301.5	301.5	301.5	301.5	301.5	301.5	301.5
Weaning Weight (lbs)	577.5	577.5	582.5	587.5	592.4	602.4	627.3

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

At the 25% protection level, there are economic benefits to the producer if calves can consistently be weaned at a weight higher than the base. Table 6.15 shows that, if rates of daily weight gain increase by 10%, annualized NPV per acre converted increases by $6.92 and $34.36 using the twenty year NPV and NPV with perpetuity, respectively. Essentially, the producer can recoup all costs of riparian protection if the producer can realize 10% higher daily weight gain at the end of the grazing season. The average calf must be sold at a market weight of 627.3 lbs which is approximately 8.6% heavier than the base case weaning weight. The annual economic benefit for the producer of protecting a total of 63.2 acres of riparian acreage is $2,171.62 at an 8.6% increase in weaning weight in perpetuity accounting for the capital and maintenance costs of the BMP. The cash flow differences at this protection level with a 10% increase are statistically significant from zero (Figure 6.9).

Figure 6.9 - Difference in cash flows between BMP #5 with a 10% increase in calf weights and the base case at the 25% protection level



6.2.1.3 BMP #6: Off-Stream Watering with Cattle Exclusion

Tables 6.16 and 6.17 display a summary of the simulation results for alternative daily calf weight gain increases, while utilizing complete exclusion fencing at the 100% and 25% protection levels, respectively. Tables M.11 and M.12 in Appendix M displays complete summary statistics.

Once again, the difference between this BMP and BMP #5 is that livestock are completely removed from riparian areas at respective protection levels in BMP #6. This reduces the number of acres available for grazing and thus reduces grazing season length and lowers calf weaning weights. This all adds up to a decrease in yearly cash flows and the resulting NPV. This decrease in NPV is shown in the tables. The twenty year NPV and the NPV with perpetuity are lower than that of BMP #5, as is the beef enterprise NPV. The yearly forage sales mean and thus the crop enterprise NPV is reduced as well, as more feed is needed for winter feeding.

The grazing season and weaning weights are the lowest at the 100% protection level as the most acreage is being removed from grazing. This removal of acreage, the loss of grazing days and the cost of BMP implementation leads to an annualized reduction in NPV even with a 10% increase in calf weight gains per day. The reduction equals $103.20 with the twenty year NPV and $104.55 for the NPV with perpetuity showing that the cost still exceeds any payoff from productivity gains in terms of calf weight gain.

Table 6.14 - Comparison of summary statistics for BMP #6 at the 100% protection level at different daily weight increases of grazing calves

			Daily Weight Gain Increase of Grazing Calves				
	Farm Base	No Prod. Gain	1%	2%	3%	5%	10%
Farm NPV Mean	$ 4,607,467	$ 4,287,273	$ 4,299,332	$ 4,311,500	$ 4,322,345	$ 4,342,476	$ 4,385,347
St. Dev.	$ 771,811	$ 770,676	$ 770,444	$ 769,843	$ 767,968	$ 763,639	$ 761,931
NPV with Perpertiuty	$ 5,433,750	$ 5,091,708	$ 5,106,224	$ 5,120,826	$ 5,133,866	$ 5,157,817	$ 5,208,731
Total NPV Change							
Twenty Year NPV Mean		$ (320,193)	$ (308,135)	$ (295,967)	$ (285,122)	$ (264,991)	$ (222,120)
NPV with Perpertiuty		$ (342,042)	$ (327,526)	$ (312,924)	$ (299,884)	$ (275,933)	$ (225,019)
NPV Change/Acre							
Twenty Year NPV Mean		$ (1,266.59)	$ (1,218.89)	$ (1,170.75)	$ (1,127.86)	$ (1,048.22)	$ (878.64)
NPV with Perpertiuty		$ (1,353.01)	$ (1,295.59)	$ (1,237.83)	$ (1,186.25)	$ (1,091.51)	$ (890.11)
Annualized Change/acre							
Twenty Year NPV Mean		$ (148.77)	$ (143.17)	$ (137.52)	$ (132.48)	$ (123.12)	$ (103.20)
NPV with Perpertiuty		$ (158.92)	$ (152.18)	$ (145.40)	$ (139.34)	$ (128.21)	$ (104.55)
Annual Forage Sales Mean	$ 45,333	$ 43,975	$ 43,975	$ 43,975	$ 43,975	$ 43,975	$ 43,975
St. Dev	$ 6,328	$ 6,276	$ 6,276	$ 6,276	$ 6,276	$ 6,276	$ 6,276
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,063,754	$ 3,063,754	$ 3,063,754	$ 3,063,754	$ 3,063,754	$ 3,063,754
St. Dev	$ 722,466	$ 721,488	$ 721,488	$ 721,488	$ 721,488	$ 721,488	$ 721,488
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,295	$ 1,149,975	$ 1,162,531	$ 1,173,981	$ 1,195,486	$ 1,241,790
St. Dev	$ 182,402	$ 182,402	$ 182,441	$ 182,219	$ 180,418	$ 177,111	$ 176,249
Grazing Season Days	301.5	301.5	294.7	294.7	294.7	294.7	294.7
Weaning Weight (lbs)	577.5	577.5	571.1	575.9	580.8	590.5	614.8

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

Table 6.15 - Comparison of summary statistics for BMP #6 at the 25% protection level at different daily weight increases of grazing calves

			Daily Weight Gain Increase of Grazing Calves				
	Farm Base	No Prod. Gain	1%	2%	3%	5%	10%
Farm NPV Mean	$4,607,467	$ 4,502,764	$ 4,514,053	$ 4,524,752	$ 4,534,669	$ 4,554,788	$ 4,596,524
St. Dev.	$ 771,811	$ 771,807	$ 770,131	$ 767,602	$ 765,436	$ 763,182	$ 766,970
NPV with Perpertiuty	$5,433,750	$ 5,322,892	$ 5,336,456	$ 5,349,226	$ 5,361,010	$ 5,384,950	$ 5,434,431
Total NPV Change							
Twenty Year NPV Mean		$ (104,703)	$ (93,413)	$ (82,715)	$ (72,797)	$ (52,679)	$ (10,942)
NPV with Perpertiuty		$ (110,858)	$ (97,294)	$ (84,524)	$ (72,740)	$ (48,800)	$ 681
NPV Change/Acre							
Twenty Year NPV Mean		$ (1,656.69)	$ (1,478.06)	$ (1,308.78)	$ (1,151.86)	$ (833.52)	$ (173.14)
NPV with Perpertiuty		$ (1,754.08)	$ (1,539.46)	$ (1,337.41)	$ (1,150.95)	$ (772.16)	$ 10.77
Annualized Change/acre							
Twenty Year NPV Mean		$ (194.59)	$ (173.61)	$ (153.73)	$ (135.30)	$ (97.91)	$ (20.34)
NPV with Perpertiuty		$ (206.03)	$ (180.82)	$ (157.09)	$ (135.19)	$ (90.70)	$ 1.26
Annual Forage Sales Mean	$ 45,333	$ 44,999	$ 44,999	$ 44,999	$ 44,999	$ 44,999	$ 44,999
St. Dev	$ 6,328	$ 6,314	$ 6,314	$ 6,314	$ 6,314	$ 6,314	$ 6,314
Crop Enterprise NPV Mean	$3,098,460	$ 3,089,910	$ 3,089,910	$ 3,089,910	$ 3,089,910	$ 3,089,910	$ 3,089,910
St. Dev	$ 722,466	$ 722,148	$ 722,148	$ 722,148	$ 722,148	$ 722,148	$ 722,148
Beef Enterprise NPV Mean	$1,173,295	$ 1,173,295	$ 1,176,096	$ 1,187,558	$ 1,198,155	$ 1,219,777	$ 1,264,766
St. Dev	$ 182,402	$ 182,402	$ 180,893	$ 179,042	$ 177,199	$ 177,107	$ 178,835
Grazing Season Days	301.5	301.5	299.8	299.8	299.8	299.8	299.8
Weaning Weight (lbs)	577.5	577.5	579.6	584.6	589.5	599.4	624.2

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

At the 25% protection level, using the NPV with perpetuity and a 10% daily calf weight gain increase, the costs of BMP implementation can be recouped. Using the twenty year NPV this is not the case.

6.2.2 Pasture Utilization Increases

6.2.2.1 BMP #4: Off-Stream Watering

The following section provides a discussion of the simulation results associated with improvements in pasture utilization of the herd attributable to implementation of off-stream watering sites. Complete summary statistics are shown in Table M.13 in appendix M. As discussed in Chapter 5, it is assumed here that livestock will over time learn to utilize upland grazing pasture more effectively with the availability of an upland water source even without riparian fencing.

Table 6.18 shows the results and the benefits to the producer resulting from cattle making better use (i.e., utilization) of the pasture. At the 3% and 6% utilization increase, the economic benefits over the twenty year period are $32,155 and $95,151, respectively. In perpetuity, the economic benefit at each utilization increase is $45,490 and $122,085, respectively.

To reiterate, the proper grazing factor which determines pasture utilization accounts for the fact that livestock may not utilize all of the entire land area (Section 5.2.4.2). The model assumes that each acre of grazing land is utilized better and with a grazing pasture of over 9000 acres, this can add up to a significant increase in forage availability. Improved utilization can come in many different forms. Improved utilization can stem from cattle grazing upland acreage that was previously never grazed. On a farm of this size, it is reasonable to assume that some pasture was at a sufficient distance from a water source that livestock would not travel to access it.

Related to this result, cattle utilizing this previously ungrazed pasture will allow pasture that may have been overgrazed due to its close proximity to a water source to recover and rejuvenate. Any reduction in over-grazing of pasture acres improves pasture health. This is not only a benefit for the current year's grazing but also for subsequent grazing seasons as health is maintained and ensured. Indirectly, the better usage of grazing acreage by livestock increases the utilization factor. This factor accounts for the pasture trampling and damage that is caused as livestock remains in a small pasture area around water sources. As livestock moves away from these areas, the biophysical effects of livestock are reduced and this is another contributing factor to pasture health.

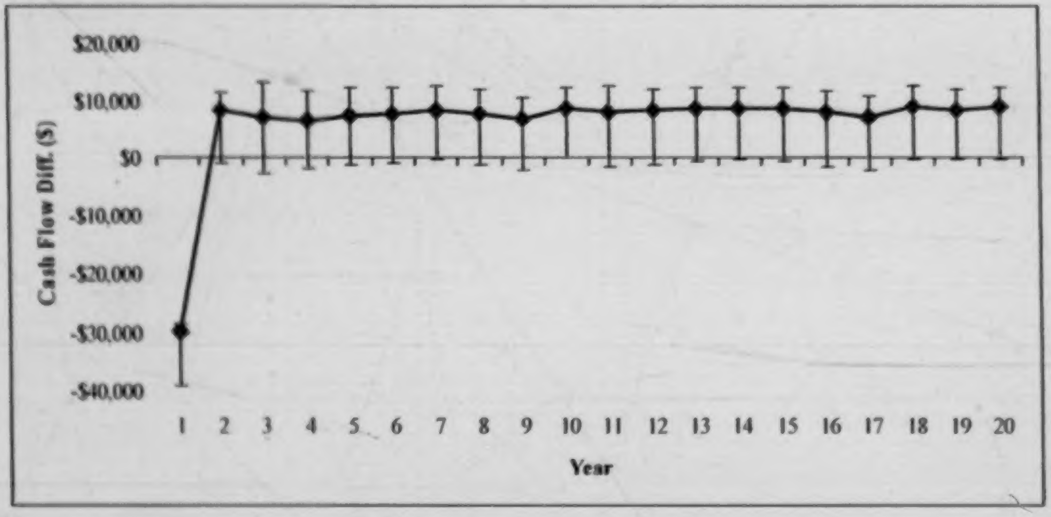
The economic benefit represented by the increased NPVs results from a lengthened grazing season due to better utilization of pasture. Table 6.18 shows the increases in grazing season days with an increase in grazing pasture utilization. The grazing season extends by as many as 15 days with a 6% increase in utilization. This increase in the grazing season has a number of effects on the profitability of the farm. The grazing season leads to heavier weaning weights, increasing revenues for the beef enterprise as well as a lower winter feed cost for the herd. With a decrease in winter feed demand, feed inventory is accumulated faster and thus there is an increase in forage sales contributing to the crop enterprise NPV. The combined effect is to increase profitability of the entire farm. This is shown below in Table 6.18. Figure 6.10 shows the differences in cash flows between the base and this simulation and at a utilization above 3%. The increase in cash flows is statistically different from zero.

Table 6.16 - Comparison of summary statistics of BMP #4 at different increases in grazing pasture utilization

			Utilization Increase	
	Farm Base	No Prod. Gain	3%	6%
Farm NPV Mean	$ 4,607,467	$ 4,574,633	$ 4,639,622	$ 4,702,618
St. Dev.	$ 771,811	$ 771,811	$ 768,489	$ 767,166
NPV with Perpertiuty	$ 5,433,750	$ 5,400,011	$ 5,479,240	$ 5,555,835
Total NPV Change				
Twenty Year NPV		$ (32,834)	$ 32,155	$ 95,151
NPV with Perpetuity		$ (33,739)	$ 45,490	$ 122,085
Annual Forage Sales Mean	$ 45,333	$ 45,333	$ 46,749	$ 48,163
St. Dev	$ 6,328	$ 6,328	$ 6,390	$ 6,454
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,098,460	$ 3,134,301	$ 3,170,058
St. Dev	$ 722,466	$ 722,466	$ 724,092	$ 725,829
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,295	$ 1,207,874	$ 1,240,288
St. Dev	$ 182,402	$ 182,402	$ 177,392	$ 176,203
Grazing Season Days	301.5	301.5	308.9	316.3
Weaning Weight (lbs)	577.5	577.5	589.7	601.9

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

Figure 6.10 - Difference in cash flows between BMP #4 and the base with a 3% pasture utilization increase



6.2.2.2 BMP #5: Off-Stream Watering with Temporary Access Fencing

In this scenario, utilization increases were simulated to determine if the costs of temporary access fencing and off-stream watering could be recouped. Complete summary statistics are shown in Table M.14 and M.15 in Appendix M. A summary of the results is provided in Table 6.19.

The implementation and reason for this BMP have been well documented in previous sections so only pertinent results will be presented and discussed here. Table 6.19 displays the impact of possible pasture utilization increases of 3% and 6%, each being modeled at the 25% and 100% riparian protection levels. At a 100% protection level, the increases in pasture utilization are not sufficient to recoup the capital costs of fencing and off-stream watering setup and the respective maintenance costs. At a 25% protection level, however, the costs are recouped assuming that the increase in utilization rate is greater than 3%. With a 6% increase in utilization, the annualized benefits per acre are $73.45 and $120.38 using the twenty year NPV and NPV with perpetuity, respectively. Annual forage sales, crop and beef enterprise NPV, grazing season days and weaning weights follow the same trend as explained in the previous section. Figure 6.11 illustrates that the differences in cash flows at the 25% protection level with a 6%

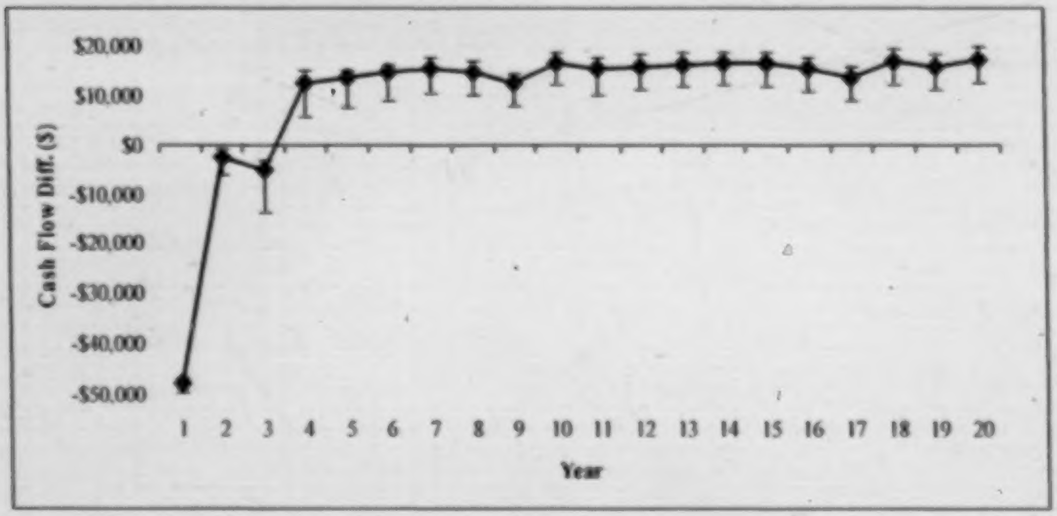
utilization increase after the three year off-stream watering and fencing setup are significantly different from zero.

Table 6.17 - Comparison of summary statistics for BMP #5 at 3% and 6% increases in grazing pasture utilization at different protection levels

	Riparian Protection Level						
		100%			25%		
	Farm Base	No Prod. Gain	3%	6%	No Prod. Gain	3%	6%
Farm NPV Mean	$ 4,607,467	$ 4,352,111	$ 4,417,101	$ 4,480,096	$ 4,519,002	$ 4,583,992	$ 4,646,987
St. Dev.	$ 771,811	$ 771,811	$ 768,489	$ 767,166	$ 771,811	$ 768,489	$ 767,166
NPV with Perpetuity	$ 5,433,750	$ 5,170,751	$ 5,249,980	$ 5,326,575	$ 5,342,696	$ 5,421,925	$ 5,498,520
Total NPV Change							
Twenty Year NPV		$ (255,355)	$ (190,366)	$ (127,370)	$ (88,464)	$ (23,475)	$ 39,521
NPV with Perpetuity		$ (262,999)	$ (183,770)	$ (107,175)	$ (91,054)	$ (11,825)	$ 64,770
NPV Change/Acre							
Twenty Year NPV Mean		$ (1,010.11)	$ (753.03)	$ (503.84)	$ (1,399.75)	$ (371.44)	$ 625.33
NPV with Perpetuity		$ (1,040.34)	$ (726.94)	$ (423.95)	$ (1,440.72)	$ (187.10)	$ 1,024.84
Annualized Change/acre							
Twenty Year NPV Mean		$ (118.65)	$ (88.45)	$ (59.18)	$ (164.41)	$ (43.63)	$ 73.45
NPV with Perpetuity		$ (122.20)	$ (85.39)	$ (49.80)	$ (169.23)	$ (21.98)	$ 120.38
Annual Forage Sales Mean	$ 45,333	$ 45,333	$ 46,749	$ 48,163	$ 45,333	$ 46,749	$ 48,163
St. Dev	$ 6,328	$ 6,328	$ 6,390	$ 6,454	$ 6,328	$ 6,390	$ 6,454
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,098,460	$ 3,134,301	$ 3,170,058	$ 3,098,460	$ 3,134,301	$ 3,170,058
St. Dev	$ 722,466	$ 722,466	$ 724,092	$ 725,829	$ 722,466	$ 724,092	$ 725,829
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,295	$ 1,207,874	$ 1,240,288	$ 1,173,295	$ 1,207,874	$ 1,240,288
St. Dev	$ 182,402	$ 182,402	$ 177,392	$ 176,203	$ 182,402	$ 177,392	$ 176,203
Grazing Season Days	301.5	301.5	308.9	316.3	301.5	308.9	316.3
Weaning Weight (lbs)	577.5	577.5	589.7	601.9	577.5	589.7	601.9

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

Figure 6.11 - Difference in cash flows between BMP #5 and the base at the 25% protection level with a 6% pasture utilization increase



6.2.2.3 BMP #6: Off-Stream Watering with Cattle Exclusion

Table 6.20 provides a summary of the significant results for the implementation of this BMP, allowing for 3% and 6% increases in pasture utilization. Tables M.16 and M.17 in Appendix M provide complete summary statistics for these scenarios.

Results from this scenario are similar to those presented in the previous section. The difference is that the NPVs have a lower magnitude due to the complete loss of grazing acres with this BMP. At a 100% riparian protection level, the capital costs of BMP implementation and the reduced revenue due to the loss of grazing acreage are not recouped if increased pasture utilization can be realized by the producer, at least for the increases modeled in this analysis. The increase in pasture utilization did increase the grazing season and weaning weights. For the scenario involving a 6% increase in utilization, mean weaning weights increased 2.2% from a 2.6% increase in the grazing season (Table 6.20). Annual forage sales and crop and beef enterprise NPVs increased with the increase in grazing season days. Overall, however, the increased revenues were insufficient to offset the cost of BMP implementation on an annualized basis.

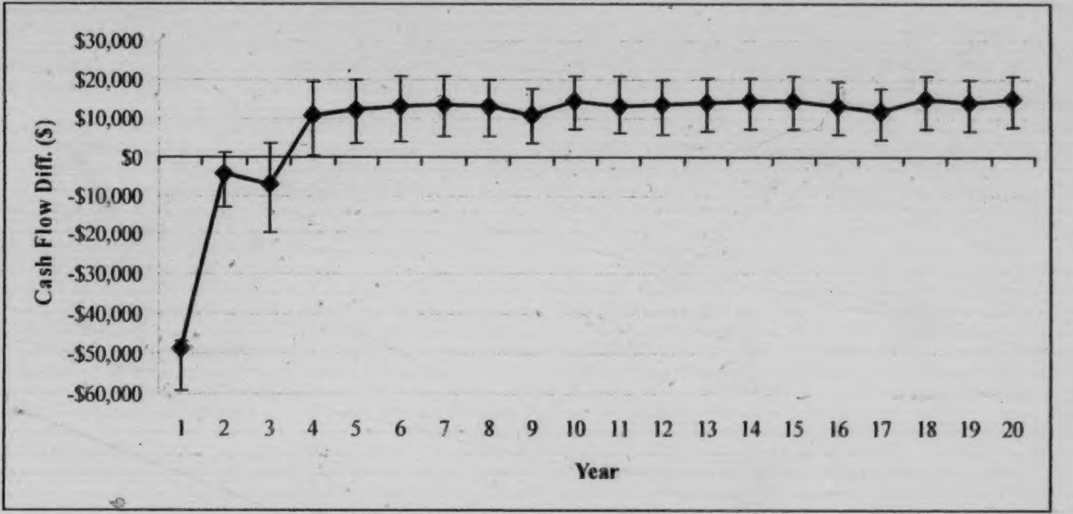
At a 25% riparian protection level, the 6% increase in pasture utilization did return a positive economic benefit on an annualized basis. As indicated in Figure 6.12, the increases in annual cash flows resulting associated with this scenario are significantly different from zero. The mean weaning weights increased 3.7% from a 4.3% increases in grazing season days at the 6% utilization increase (Table 6.20). If this increase can become consistent in the long run, then the costs can be recovered.

Table 6.18 - Comparison of summary statistics for BMP #6 at 3% and 6% increases in grazing pasture utilization at different protection levels

	Riparian Protection Level						
		100%			25%		
	Farm Base	No Prod. Gain	3%	6%	No Prod. Gain	3%	6%
Farm NPV Mean	$ 4,607,467	$ 4,287,273	$ 4,356,673	$ 4,421,728	$ 4,502,764	$ 4,568,758	$4,632,484
St. Dev.	$ 771,811	$ 770,676	$ 771,700	$ 768,197	$ 771,807	$ 768,642	$ 767,367
NPV with Perpertiuty	$ 5,433,750	$ 5,091,708	$ 5,176,505	$ 5,255,787	$ 5,322,892	$ 5,403,386	$5,480,950
Total-NPV Change							
Twenty Year NPV		$ (320,193)	$ (250,793)	$ (185,739)	$ (104,703)	$ (38,709)	$ 25,017
NPV with Perpetuity		$ (342,042)	$ (257,245)	$ (177,963)	$ (110,858)	$ (30,364)	$ 47,200
NPV Change/Acre							
Twenty Year NPV Mean		$ (1,266.59)	$ (992.06)	$ (734.73)	$ (1,656.69)	$ (612.49)	$ 395.84
NPV with Perpertiuty		$ (1,353.01)	$ (1,017.58)	$ (703.97)	$ (1,754.08)	$ (480.44)	$ 746.84
Annualized Change/acre							
Twenty Year NPV Mean		$ (148.77)	$ (116.53)	$ (86.30)	$ (194.59)	$ (71.94)	$ 46.50
NPV with Perpertiuty		$ (158.92)	$ (119.52)	$ (82.69)	$ (206.03)	$ (56.43)	$ 87.72
Annual Forage Sales Mean	$ 45,333	$ 43,975	$ 45,426	$ 46,841	$ 44,999	$ 46,419	$ 47,833
St. Dev	$ 6,328	$ 6,276	$ 6,332	$ 6,394	$ 6,314	$ 6,375	$ 6,439
Crop Enterprise NPV Mean	$ 3,098,460	$ 3,063,754	$ 3,100,398	$ 3,136,214	$ 3,089,910	$ 3,125,847	$3,161,594
St. Dev	$ 722,466	$ 721,488	$ 722,540	$ 724,193	$ 722,148	$ 723,683	$ 725,425
Beef Enterprise NPV Mean	$ 1,173,295	$ 1,173,295	$ 1,176,456	$ 1,211,123	$ 1,173,295	$ 1,199,871	$1,233,073
St. Dev	$ 182,402	$ 182,402	$ 181,621	$ 177,388	$ 182,402	$ 177,918	$ 176,765
Grazing Season Days	301.5	301.5	302.1	309.4	301.5	307.2	314.6
Weaning Weight (lbs)	577.5	577.5	578.4	590.6	577.5	586.9	599.0

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

Figure 6.12 - Difference in cash flows between BMP #6 and the base at the 25% protection level with a 6% pasture utilization increase



6.2.3 Discount Rate Sensitivity

The final sensitivity analysis evaluated the effect of alternate discount rates on the NPVs for the representative farm. As discussed in Chapter 5 (section 5.3.5), the discount rate used for the analyses discussed previously in this chapter was 10%. However, some calculations done for the farm (also discussed in Chapter 5) suggested that a discount rate of 7.5% would be appropriate for the farm. The sensitivity analysis considered in this section compares NPV results for discount rates that are higher (12.5%) and lower (7.5%) than the base rate. To assess whether the discount rate has a potentially significant impact on the BMP results in this study, this sensitivity analysis is conducted using BMP #4 (i.e., implementation of off-stream watering with no restriction of access to riparian areas) with improvements in daily calf weight gains (i.e., the BMP scenario considered earlier in Section 6.2.1.1). Table 6.21 provides a summary of the simulation results for the sensitivity analysis.

The first comparison was made between the farm NPVs for the base scenario at the various discount rates. Table 6.21 displays the change in the twenty year NPV and NPV with perpetuity for the farm as well as the change in NPV for each enterprise. The twenty year NPV and NPV with perpetuity were quite sensitive to the level of the discount rate. At the 7.5% discount rate, the twenty year NPV increased nearly just over $900,000 (19.68%) and the NPV with perpetuity increased over $1,800,000 (33.59%), compared to NPVs calculated using the 10% discount rate. The NPV of the crop and beef enterprise increased approximately $610,000 (19.72%) and $230,000 (19.54%) respectively, at the 7.5% discount rate. The opposite case was true when the discount rate was increased to 12.5%. The twenty year NPV of the base farm decreased $685,703 (-14.88%) and the NPV with perpetuity decreased $1,090,268 (-20.06%). The NPV of the crop and beef enterprises decreased 14.88% and 14.80%, respectively.

This general trend is true for all NPV comparisons at the 7.5% and 12.5% discount rate. At a 7.5% discount rate, the NPV is higher for BMP implementation with and without productivity gains from off-stream watering sites. The opposite is true at the 12.5% discount rate; all NPVs decrease with respect to the 10% discount rate.

Interestingly, at the lower discount rate of 7.5%, the sensitivity of daily calf weight increases shows that the cost of BMP implementation can be recouped at a lower daily percentage increase. Relative to the 10% discount rate scenario, under the assumption of no productivity gains, the cost of implementation decreases $4,536 (16.02%) and $5,442 (19.23%) using the twenty year NPV and NPV with perpetuity, respectively. At the 10% discount rate, daily weight gains of in excess of 3% and 2% are needed for an NPV increase for the twenty year NPV and NPV with perpetuity respectively (Table 6.13 and 6.21). When the discount rate is 7.5%, the daily weight gain increases to recover implementation costs are lowered to 2% and 1% at with the twenty year NPV and NPV with perpetuity, respectively. At a 10% daily calf weight gain increase, the benefit of BMP implementation increases $23,487 (39.57%) and 43,686 (57.63%) with the twenty year NPV and NPV with perpetuity respectively. Reducing the discount rate made BMP implementation more attractive.

Increasing the discount rate to 12.5% made BMP implementation less attractive relative to the base discount rate of 10% (Table 6.20). With no productivity gains, the cost of BMP implementation increased $3,906 (11.89%) and 2,301 (6.8%) for the twenty year NPV and NPV with perpetuity, respectively At a 10% daily calf weight gain increase, the NPV increase was reduced by $25,469 (42.91%) and $33,063 (43.62%) for the twenty year NPV and NPV with perpetuity, respectively.

Table 6.19 - Comparison of representative farm NPV statistics using a 7.5% and 12.5% discount rate compared to the base discount rate of 10% for the implementation of BMP #4 with productivity increases

			Daily Weight Gain Increase of Grazing Calves				
	Base	No Prod. Gain	1%	2%	3%	5%	10%
Farm NPV Mean (7.5%)	$ 5,514,380	$ 5,486,082	$ 5,498,857	$ 5,511,003	$ 5,523,789	$ 5,546,196	$ 5,597,218
Farm NPV Mean (10%)	$ 4,607,467	$ 4,574,633	$ 4,585,216	$ 4,595,289	$ 4,605,896	$ 4,624,491	$ 4,666,818
Farm NPV Mean (12.5%)	$ 3,921,764	$ 3,885,024	$ 3,891,660	$ 3,900,173	$ 3,910,140	$ 3,926,865	$ 3,955,646
NPV with Perpetuity (7.5%)	$ 7,259,205	$ 7,230,908	$ 7,248,064	$ 7,264,231	$ 7,281,261	$ 7,311,055	$ 7,378,694
NPV with Perpetuity (10%)	$ 5,433,750	$ 5,400,011	$ 5,412,647	$ 5,424,647	$ 5,437,264	$ 5,459,357	$ 5,509,553
NPV with Perpetuity (12.5%)	$ 4,343,482	$ 4,307,442	$ 4,315,437	$ 4,323,922	$ 4,331,915	$ 4,350,426	$ 4,386,222
Total NPV Change							
Farm NPV Mean (7.5%)		-$ 28,298	-$ 15,523	-$ 3,377	$ 9,409	$ 31,816	$ 82,838
Farm NPV Mean (10%)		-$ 32,834	-$ 22,251	-$ 12,178	-$ 1,570	$ 17,024	$ 59,352
Farm NPV Mean (12.5%)		-$ 36,740	-$ 30,104	-$ 21,591	-$ 11,624	$ 5,101	$ 33,882
NPV with Perpetuity (7.5%)		-$ 28,297	-$ 11,141	$ 5,026	$ 22,056	$ 51,850	$ 119,489
NPV with Perpetuity (10%)		-$ 33,739	-$ 21,103	-$ 9,103	$ 3,514	$ 25,607	$ 75,803
NPV with Perpetuity (12.5%)		-$ 36,040	-$ 28,045	-$ 19,560	-$ 11,567	$ 6,944	$ 42,740
Crop Enterprise NPV Mean (7.5%)	$ 3,709,371	$ 3,709,371	$ 3,709,371	$ 3,709,371	$ 3,709,371	$ 3,709,371	$ 3,709,371
Crop Enterprise NPV Mean (10%)	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460	$ 3,098,460
Crop Enterprise NPV Mean (12.5%)	$ 2,637,268	$ 2,637,268	$ 2,637,268	$ 2,637,268	$ 2,637,268	$ 2,637,268	$ 2,637,268
Beef Enteiprise NPV Mean (7.5%)	$ 1,402,559	$ 1,402,559	$ 1,415,998	$ 1,428,897	$ 1,442,552	$ 1,466,499	$ 1,521,151
Beef Enterprise NPV Mean (10%)	$ 1,173,295	$ 1,173,295	$ 1,184,500	$ 1,195,267	$ 1,206,670	$ 1,226,667	$ 1,272,293
Beef Enterprise NPV Mean (12.5%)	$ 999,623	$ 999,623	$ 1,009,139	$ 1,018,293	$ 1,027,990	$ 1,044,998	$ 1,083,793

Note: "Farm Base" refers to the base farm scenario with no BMP implemented. "No Prod. Gain" refers to the scenario with the respective BMP implemented without any productivity increases.

With both NPV calculations (twenty year and perpetuity), the daily weight gain increase required to recoup the cost of investment (i.e., result in an improved NPV relative to no adoption) with a 12.5% discount rate must be greater than 3%. However, as the discount rate increases, from 10% to 12.5%, the percentage change (reduction) in NPV is lower than that when the discount rate is reduced to 7.5%. This parallels results found by Cortus (2005), who determined that a decrease in discount rate substantially improved the attractiveness of agricultural wetland drainage and increased discount rate reduced the attractiveness of drainage but by a lower magnitude.

In conclusion, the choice of discount rate is important when performing and NPV analysis for an investment decision. As shown in Table 6.21, the magnitudes of costs or returns to BMP implementation change quite substantially. Thus measuring the impacts of alternative discount rates is worth exploring in making BMP implementation decisions.

6.3 Model Validation

In an effort to support the decision making process model verification and validation are essential. A model is likely to be questioned an unlikely to be adopted in without evidence of model verification and validation (Macal, 2005). Model verification is concerned with building the model correctly and consistently asking the question: is the logical structure and are the input parameters in the model correctly represented? Verification ensures that the model specification is complete and there are no errors or bugs. In this study, verification was performed by testing the ability of modelled relationships to replicate the intended processes. Output results from econometric crop, forage and pasture yield models were compared to historical, real life data in order to understand whether the model correctly simulated geographical yield means and variances. The representativeness of crop and beef price estimation was tested as well to assure that everything was correctly specified.

The verification of model inputs allowed for model simulation to occur for a comparison of BMP scenarios. This leads to the important task of validating the model; that is, testing to see if the model is reproducing the behaviour of the real world system and that model outputs are correctly representing this behaviour. Where model verification deals with building the model correctly, model validation deals with building the correct model. Validation addresses the questions of a) whether the model is suitable for the intended purpose, and b) are the results sensible and meaningful? Ultimately, validation works to make sure the model makes sense, effectively addresses the problem at hand, provides accurate information about the problem and that the model can actually be used (Macal, 2005).

Validation can be performed in a number of ways. Face validity asks if the model seems reasonable in terms of structure and theory. This refers to the use of procedures such as net present value analysis and stochastic simulation. Throughout the study, the use of these procedures and underlying theory has been justified. The review of previous studies on Monte Carlo simulation, NPV analysis and the use of capital market line theory has displayed the advantages of their use over other alternative approaches. Crop yield and price models are consistent and have been proven successful with previous research performed in a similar field of study (e.g., Cortus, 2005; Miller, 2002).

With the complexity of this model, merely validating the modelling procedures based on previous studies was not sufficient. In the same regard, the complexity of the model makes it difficult to rigorously perform model validation. Simulation results are based on an actual representative farm for the area so one would assume that it is possible to seemingly compare the simulation output results with the actual performance of the farm. This is not possible due to the limited financial information available and the fact that some of the farm relationships were not modelled the same as what would be seen in reality. An example of this is calculating the value and costs associated with the machinery complement. There were no data for the machinery used by the farm in the Lower Little Bow so a machinery complement was developed based on what would be expected on a farm of this size.

However, it is possible to examine the validity of the model by using simulation model output. In the case of BMP #3, conversion of cropland to permanent cover with cattle exclusion, the cost of conversion from full crop production to no agricultural activities, in terms of income given up by the producer, may be considered as the opportunity cost of lost production. The annualized decrease per acre of land converted is representative of the opportunity cost of converting the land out of production and adding fencing to protect riparian areas from cattle access. Removing the cost of fencing ($29.90 or $30.81/acre) leaves an average annualized cost per acre of $119.78 or $146.00 in perpetuity (see Section 6.1.2.3). For producers, this opportunity cost to production should approximate the rental rate of land (Unterschultz, 2008; AARD, 2007-d).

A comparison is performed between cropland rental rates in southern Alberta and the results of this simulation to determine the representativeness of simulation results and the costs associated with taking land out of production. One way of determining a cash rental rate is by calculating the contribution margin (direct revenues less direct expenses) and splitting that margin in half to allow the possibility for the renters to makes a profit. If rental rates are charged at the contribution margin, renters would make no margins off crop production and thus not rent and thus the contribution margin is split (AARD, 2007-d). In this analysis, the annualized cost is a close representation of the contribution margin for land productivity. It can thus be used as an approximation of the contribution margin for crop production. However, this annualized cost per acre is derived from the difference in the entire farm's NPV which includes the beef enterprise. Thus the annualized decrease in crop enterprise NPV is also calculated to find the possible cash rental rate cropland. Table 6.20 compares the annualized cost per acre using the total farm NPV differences, the crop enterprise NPV differences and the rental rates for southern Alberta calculated by Alberta Agriculture and Rural Development (AARD, 2008-e). Based on this comparison, the simulation effectively represents the opportunity cost of taking cropland out of production which can be interpreted as the value of land rental rates for the area.

6.20 - Comparison of Annualized Cost per Acre of Conversion for BMP #3 and Cropland Rental Rates per Acre for Southern Alberta

20 Year NPV	NPV with Perpetuity	Crop Enterprise	Cropland Rental Rate (AARD)
$59.89	$73.00	$61.06	$69.15

Note: Rental rate for southern Alberta is the average rental rate between dryland and irrigated averaged over the years 2006 and 2007

A similar analysis is done with BMP #6. This BMP involves completely removing access for cattle to the pasture area that is converted to a buffer strip. With this BMP, similar to BMP #3, the annualized decrease per acre of land protected and not exposed to grazing should be representative of the opportunity cost to grazing or rental rate for pasture. Using BMP #6, off-stream watering with cattle exclusion, the annualized cost per acre average calculated at the farm level is adjusted by the cost of fencing and off-stream watering site establishment to attain an average cost of protection per acre and cost per AUM of $30.98/acre[28] or $35.45/AUM using the twenty year NPV. This equals $36.89/acre or $42.19/AUM using the NPV with perpetuity. The annualized cost per acre can be derived from the beef enterprise NPV results. Alberta Agriculture and Rural Development has statistics on the historical pasture cash rental rates on a $/acre basis as well as a $/AUM basis back to 2005. Table 6.21 compares the pasture rental rates calculated at the farm level and beef enterprise level to those from Alberta Agriculture and Rural Development.

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[28] The cost per acre was calculated by running two simulations. The first was BMP #6 with fencing included and the second was BMP #6 where pasture land was converted but not fenced and no off-stream waterer provided. The difference between the two is that the capital and maintenance costs are not included in the second scenario leaving just the opportunity cost of converted pasture land to riparian habitat.

6.21 - Comparison of Annualized Cost per Acre of Conversion for BMP #6 and Pasture Land Rental Rates per Acre for Southern Alberta

	20 Year NPV	NPV with Perpetuity	Beef Enterprise	Pastureland Rental Rates (AARD)
$/acre	$30.98	$36.89	$16.78	$10-$30
$/AUM	$35.48	$42.19	$19.22	$17-$30.75

The $/AUM values was calculated by dividing the $/acre by AUM/acre representative of the riparian acreage of the farm. AUM/acre is a weighted average of the AUM values for riparian native and tame pasture acreage.

$$((1280 \text{ acres}/9120 \text{ acres})*3.08 \text{ AUM's/acre} + (7840 \text{ acres}/9120 \text{ acres})*0.52 \text{ AUM's/acre}) = 0.8732 \text{ AUM's/acre} \qquad (6.2)$$

Based on this, the opportunity cost of protecting riparian acreage from grazing is comparable to the pasture rental rate ranges that are provided by AARD for southern Alberta. Using the twenty year NPV and NPV with perpetuity may overestimate the rental rates, but these values include all changes that occur in the rest of the farm not related to the beef enterprise. The beef enterprise opportunity costs fall within the range of what AARD deems accurate for pasture rental rates in southern Alberta supporting the representativeness of this simulation model for a southern Alberta mixed farm operation.

6.4 Chapter Summary

There were six best management practice scenarios studied in this analysis; three for cropland and three for pasture land. BMPs #1, #2 and #3 were implemented on cropland to protect water and riparian habitats. The simulation results for these scenarios suggested that it was not economically feasible for the producer to implement any one of these BMPs. The loss of productive cropland and conversion to permanent cover or riparian habitat reduced the profitability of the farm, as measured by the NPV. The farm was still profitable in each scenario (i.e., the NPVs were numerically significant and positive) but there was a drop in net present value relative to the base scenario with no BMP adoption. The equivalent annual cost per acre of cropland conversion ranged from $40.24 to $179.89. BMP #3, which involved converting all cropland to riparian habitat, was the most costly BMP to implement. This is not surprising given that the land is completely removed from agricultural production. A comparison of the equivalent annual cost and cropland rental rates in southern Alberta suggested that the opportunity costs of conversion suggested by the simulation model results were similar to rental rates in the region. This demonstrates the validity of the model results in terms of calculating the benefits/costs to the producer with various BMP implementation scenarios.

BMPs #4, #5 and #6 were imposed on pasture land. Each involved off-stream watering with varying degrees of access to riparian areas. The costs/benefits for these BMPs were analyzed with and without productivity gains in the form of increased calf weight gains and increased pasture utilization. Without productivity increases, these pasture BMPs cost producers up to $158.92 per acre converted from grazing pasture to riparian habitat. The bulk of this cost comes from the fencing of riparian habitat. Fencing makes up a large portion of cost for any of the BMPs where fencing is installed.

With productivity gains, the negative impact on NPV was reduced, as the productivity gains at least partially offset the costs of BMP implementation. In fact, there were instances where the cost of investment was recouped, resulting in increased NPV relative to the base scenario with no BMP adoption. The productivity gains with increased calf weaning weights and pasture utilization were modeled based on the vast literature suggesting that livestock productivity responds to cleaner water and a change in behaviour with an off-stream watering source.

BMP #4, which provides livestock with an off-stream watering source with no fencing of riparian habitat, provides the greatest economic gain for the producer if cattle productivity responds positively as suggested by the literature. Economic gains can reach $122,085 in terms of increased perpetuity NPV, from cattle utilizing upland pasture more effectively. From a daily calf weight gain perspective, if calves can gain an extra 10% per day over the grazing season, which has been shown to be feasible in some studies, the economic benefit to the producer can reach $59,351 in terms of increased NPV over a twenty year period (Table 6.13). If riparian protection occurs at the 25% level, BMP #5 and #6 can result in improved performance (i.e., positive economic incentives) for the producer only if calves can increase their daily weight gain by 10%. BMP #4 would be most realistic of all pastureland BMPs to implement due to the economic benefit potential and the literature that states the effectiveness of off-stream watering sites on decreasing riparian habitat usage.

Chapter 7 : Conclusions, Limitations and Further Research

An economic cost/benefit analysis was performed for implementation of Best Management Practices (BMPs) by a large mixed farm in southern Alberta. The study was undertaken in order to better understand the private benefits and costs to a producer who introduces riparian habitat and water preservation and conservation practices onto their operation. The study was performed by modelling a farm representative of a large mixed crop and livestock operation in the Lower Little Bow Watershed in southern Alberta. The site was well suited for agricultural BMP analysis because of the wide range and intensities of agricultural activities associated with the operation.

Along with historical local crop yield, crop price and beef price series data provided by Alberta Agriculture and Food (Kaliel, 2007) and Agriculture and Agri-Food Canada (Ross, 2007), data were collected from local producer surveys to generate very detailed financial statistics of the farms in the area. These data were used in a Monte Carlo simulation analysis. For a base scenario and a set of BMP implementation scenarios, a Net Present Value was calculated over a twenty year period. The financial performance of the farm was simulated incorporating stochastic inputs (i.e., weather, crop prices, beef prices) to integrate risk into the simulation. Economic and biophysical relationships present on a farm of this nature were modeled. The performance of the representative farm was simulated repeatedly with many different BMPs in place and then compared to the performance of the farm with no BMP in place. These comparisons produced an understanding of the potential costs and/or benefits of BMP implementation. The key findings of these comparisons are presented in this chapter along with limitations found in this study and suggestions for further research.

7.1 Economic Feasibility of BMP Implementation

7.1.1 BMPs with No Productivity Gains

In the absence of possible productivity increases (i.e., increased calf weight or pasture utilization), implementation of BMPs for riparian and water quality preservation and conservation is costly for producers. The costs arise in the form of lower margins and reduced returns for crop and cow/calf enterprises; that is, the entire farm. This cost is attributable to reduced acreage of arable land being available for crop production, reduced pasture acreage for livestock grazing as well as the capital and maintenance cost of introducing fencing and off-stream watering sites.

In regards to the crop enterprise, the conversion of productive land from crop production to riparian habitat with permanent cover and/or buffer strips decreases the revenue stream. Although not captured in the simulation analysis, this result would be reinforced by the current increasing trend in crop prices due to higher demand for food and crops for bio-fuel production. While for some of the BMPs hay production is substituted for annual cereal/oilseed crop production, as part of the scheme to protect riparian areas and water from the impacts of intensive cropping activities, it is not economically justifiable to do so in terms of the impact on NPV. It should be noted that the decrease in revenues does not result in negative cash flows associated with agricultural production. Even after BMP implementation, the farm is still very financially healthy in terms of positive cash flows and a very positive NPV. However, the farm performs better in the base scenarios when BMPs are not implemented. At the extreme end of riparian and water protection, the complete loss of cropland acreage by way of converting it to buffer strips also reduces farm profitability. However, again this is not to the point that the farm is losing money as a whole.

A sensitivity analysis using various riparian protection levels (i.e., 25%, 50%, 75% and 100%) had no significant bearing on the conclusion that the implementation of cropland BMPs is costly to the producer. For each acre of land converted out of crop production, the total and annualized cost remained relatively the same over all protection levels. Obviously however, the more riparian acreage protected, the higher the total reduction in farm profitability.

Under the assumption of no productivity gains, the case is similar for the beef enterprise and pastureland BMPs. Implementation of these types of BMPs (i.e., providing off site watering and controlling/restricting access to pastureland adjacent to waterways) resulted in reduced profitability for the farm. This was largely due to the large capital and maintenance costs of supplying off-stream watering sources to the cattle and building fences lines along riparian zones. The most protectionist grazing pasture BMP completely excluded cattle from accessing riparian zones so this loss of grazing potential also had a direct effect on the farm's bottom line by reducing the grazing season and thus the calf weaning weights. The loss in access to pastureland resulted in lower calf weaning weights. This in turn led potentially to increased winter feed costs and even (in some cases) reduced calf sale weights. In these instances, revenues from sales of calves were reduced. A sensitivity analysis with alternative degrees of protection, while changing the magnitude of the effects, resulted in the same overall conclusions; that is, adoption of these pastureland BMPs is costly to producers.

7.1.2 Productivity Gains

Previous literature had suggested the possibility of productivity gains associated with some types of BMPs. Productivity increases came in two forms. The first of these was increased calf weight gains over the grazing season from drinking water supplied from an off-stream watering site. Increased calf weight gains led to heavier calf weights off pasture and a higher selling weight. The second source of productivity gain was an increase in pasture utilization where the presence of an off-stream watering site would draw livestock to make use of upland areas better than before. This ultimately leads to a longer grazing season, increased rates of calf weight gains and higher selling weights.

When the possibility of these types of productivity gains were taken into account for the pastureland BMPs, in most cases BMP implementation still reduced the profitability of the farm. However, when the results were subjected to a sensitivity analysis for the degree of improvement in calf weight gain, the results did vary depending upon which BMP was being implemented. For the BMP scenario where off-stream watering was provided with no restrictions on access to riparian areas, the implementation proved to be economically justifiable and attractive if the percentage daily weight gain increase was over 3% each year. Economic benefits are statistically significant at percentage increases above 5%. However, these potential calf weight gains are not enough to offset the capital and maintenance costs of establishing fencing to protect riparian zones with the other pastureland BMPs, off-stream watering with temporary cattle access and off-stream watering with cattle exclusion. Only at the 25% protection level and a 10% daily calf weight increase were net economic benefits realized after the implementation of these BMPs. These benefits were only statistically significant however for off-stream watering and temporary cattle access.

Similar to calf weight improvements from off-stream watering sites, previous literature has suggested that off-stream watering sites are an effective tool to draw livestock away from riparian zones and natural sources of water. This results in improved upland pasture utilization and economic benefits. This was the case for pastureland BMP #4 as well as BMP #5 and #6 at the 25% protection level. All economic improvements were statistically significant. These economic improvements were greater than those provided by the sensitivity analysis of calf weight increases. With BMP #4, $122,085 was the highest economic benefit from a 6% pasture utilization increase, compared to a $75,803 increase with a 10% increase in the daily calf weight gains.

7.2 Implications for Riparian Area and Water Conservation

The overriding conclusion in this study is that best management practice implementation for riparian and water protection is costly to producers. Unless productivity improvements can be realized, the removal of crop and pasture acreage as well as the capital and maintenance costs of off-stream watering and fencing development will reduce the profitability of the farm. The results of this study present the costs and/or benefits on a per acre converted or protected basis and should be applicable to other farms in the Lower Little Bow Watershed. Literature regarding producer behaviour and objectives suggest that agricultural producers attempt to minimize cost (Tauer, 1995) or maximize profit (Paris and Herdt, 1991; Young and Shumway, 1991). Under either behavioural assumption, producers may need to be provided with economic incentives (e.g., direct payment) in order to implement best management practices. Otherwise, riparian and water conservation may not occur. Adding a cost to the operation that does not return a net benefit is unattractive for these producers even though it may help in maintaining or improving riparian area health and water quality. Some sort of compulsory or incentive based voluntary program may need to be established to convince producers to implement pollution prevention measures.

Historical BMP adoption programs have been non-compulsory, leaving the decision as to participation on the shoulders of producers themselves. Numerous educational programs[29] and government assistance programs for volunteering to engage in environmental protection[30] have been used to encourage producers to become actively involved in environmental point and non-point source pollution prevention. Logan (1990) argues that a voluntary best management practice system has many benefits over a mandatory or compulsory system. The voluntary approach appeals to the majority of farmers who are very independent and want to be in control of their privately owned land rather than being told what to do (Cunningham, 2003). Producers' expertise with respect to site specific characteristics, flexibility in the farmer's ability to adopt and maintain the practice along with no enforcement and low costs required are major advantage of voluntary programs. Compulsory implementation programs pass the capital and maintenance costs onto farm operators (Logan, 1990)

The economic costs of BMP implementation presented and discussed in Chapter 6 can serve as a proxy in deciding potential appropriate subsidization rates or incentive values required to convince producers to implement BMPs. One such proxy is the annualized cost per acre values that were calculated. These values can be paid to producers in response to implementing one or more of the BMPs analyzed in this study. Rental rates for land in southern Alberta can also be used as a proxy to compensate producers to implement BMPs and remove acreage from production. Essentially, a governing body promoting BMP implementation can rent the land from producers at local rental rate to institute environmental protection.

Relaxing the assumption of strict cost minimization and profit maximization, it needs to be recognized that there are producers who would voluntarily adopt BMPs. Mostaghimi et al. (1995) surveyed producers in the Chesapeake Bay of Virginia and concluded that BMP adoption is highly influenced by producer's farm income level, the existence of a conservation plan, age and a general concern for environmental and water quality problems. It cannot be ignored that producers do have a general concern for environmental protection. Cunningham (2003) assessed the differences in the quality of the BMPs being implemented in the James River Basin in Virginia between cost-shared BMPs and non cost-shared BMPs. Cost-shared BMPs were those where the producers were forced to comply with state standards and the implementation costs were covered. Non cost-shared BMPs were not subject to any standards and completely implemented by the producers. BMP quality was measured in terms of design, site selection, implementation and maintenance. Sixteen BMP types were compared including buffer strips, stream fencing, and stream bank stabilization techniques. Results concluded that there was no statistically significant difference in the quality of BMP implemented between state enforced BMPs and those that were engineered exclusively by farmers in the basin. Understanding that producers are aware of their environmental impact, producers may be open to cost-shared programs in an effort to promote riparian health and water quality maintenance.

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[29] See section 2.5.1 for a discussion of historical BMP educational programs.

[30] See section 2.5.1 for a discussion of government programs.

7.3 Model Limitations and Assumptions

It needs to be recognized that the results of this study are directly related to the characteristics of the representative farm in the Lower Little Bow. However detailed and concise the modelling is, it is not realistic to apply these numbers in all situations where riparian best management practices are being implemented. A number of assumptions needed to be made based on some limited data regarding the farm's characteristics. However, one can be confident that these results can be used as representative of the Lower Little Bow Watershed with the data series used representative of local producers, weather, crop yields and commodity prices.

Even though the costs and/or benefits are representative of riparian acreage conversion and protection in the Lower Little Bow Watershed, this study did not simulate the financial performance of farms of different sizes or enterprise mixes. Conducting the same analysis for a smaller farm in terms of land base and herd size may have produced a different set of results. Due to the size and thus profitability of the modelled farm, the cost to implement BMPs does not have a large impact on the bottom line. However, approximately 94% of the farms in the area have a smaller land base and 87% of them have lower total gross farm receipts. The impact of the cost of BMP implementation may be substantially larger making it even more unattractive to implement. However, under the assumption of riparian acreage making up 2% of the land base, there would be less acreage to protect, thus decreasing capital and maintenance costs. The conclusion of homogenous conversion and protection costs across farms can therefore be questioned without explicitly modelling all situations. Furthermore, the model output cannot be used to represent other geographical areas. A farm in a different geographical area under different soil and weather conditions may have significantly different crop mixes and crop and pasture yield magnitudes.

In this study, outputs are limited to the assumptions concerning the farm's cow/calf herd, crop mix and rotation. Due to modelling complexities and the focus on analyzing BMP implementation, these assumptions needed to be made. The pasture base found on the representative farm allows producers to easily expand herd size. It may be possible to increase the herd size in an effort to make up for the cost of BMP implementation but this was not explored. The assumption of a constant herd size eliminated the impact of drought conditions and feed availability which may force producers to reduce herd size.

Over time, in response to soil conditions and other biophysical changes as well as weather and crop price trends, the crop mix may change. This would affect crop revenues and input costs. This change may increase or decrease the attractiveness of cropland conversion. For the geographical area being studied, a seven year alfalfa stand or hay production may not be optimal but this possibility was not explored. Perhaps a shorter hay rotation is more profitable. The model also did not perform comparisons of crop-livestock mixes. A larger or smaller proportion of cropland to pastureland may have many effects on farm performance. Any changes in these assumptions could possibly change the results of the study.

The concept of a modified net cash flow was developed in this study and therefore a select number of costs were used in the study. Fixed costs were not included in the net present value analysis for the reason that they would not change with each BMP scenario or sensitivity analysis. The results of the NPV analysis are also highly dependent upon the discount rate used for the simulation. A discount rate of 10% was used to be consistent with other agricultural NPV studies and it seems to be the discount rate of choice for most analyses. This was done contrary to the finding that the discount rate for the farm is approximately 7.5%. Sensitivity around the discount rate was performed on one scenario and it is clear that discount rates can greatly impact results. Therefore, the reasoning of why a particular discount rate is chosen needs to be made very clear.

The most difficult component to model in this study was the measurement and representation of the size and acreage of the riparian zones. Mapping all riparian zones on the representative farm in the Lower Little Bow was unrealistic. Therefore, an estimation needed to be done. The assumptions made were necessary to adequately model and manipulate riparian conservation with each BMP scenario.

No field or pasture is the same in terms of the amount or placement of riparian acreage and sources of water and thus a predetermined riparian percentage was chosen. This was held constant over the study as the large amount of simulations that needed to be performed made it unrealistic to add another sensitivity altering riparian acreage size. The physical characteristics of riparian zones are also never identical. The assumption that all acreage, upland and riparian, was equally as arable and productive made for a consistent calculation of riparian acreage conversion and protection. In reality, these areas may be subject to flooding and crop yields may be lower in these areas compared to upland areas, but there was no way to model this in a straightforward and confident manner.

7.4 Further Research

The Lower Little Bow Watershed is just one of many watersheds present in Western Canada, each of which has their own unique biophysical characteristics and economic relationships. The results presented in this study cannot be applied to all areas but with appropriate data and information, the model developed here can perform the same analysis and produce results that are representative of other geographical areas. This would allow for a comparison of the costs and/or benefits of BMP implementation across regions.

This study focussed on the costs and benefits of best management practice implementation for the producer, otherwise known as the private costs and benefits. There have been a number of studies analyzing the private costs of BMP implementation and their impact on preserving riparian habitats and conserving water quality but this is only one side of the story. There is a lack of literature on the public or social benefits of

BMP implementation and a number of questions remain about the possible benefits of BMP implementation. What are the benefits to downstream water users? Those other users may be other agricultural producers, recreational users, aquatic and vegetative species or even households and municipalities that use the water as a drinking source. What will be the future benefits to the specific sites in terms of riparian health and water quality?

Depending on the type of BMP put in place, it is likely that producers will be required to be responsible for some of the costs of BMP implementation, directly or indirectly. Producers may have to buy and establish fencing exemplifying a direct cost. Indirectly, riparian protection can decrease the amount of acreage to be utilized. To fully understand the overall outcome of BMP implementation, further investigation needs to be performed to try to value environmental and societal costs and/or benefits. The concept of ecological goods and services is an approach to try to derive the societal benefits resulting from BMP implementation or other environmental conservation techniques. It is not easy to explicitly value environmental improvements as they can come many different, immeasurable forms. However, the valuation of non-market goods has been performed using various techniques including contingent valuation methods which determine the willingness-to-pay for environmental improvements. Further work is recommended to evaluate the presence of the societal and environmental benefits or costs from BMP implementation for a complete understanding of the effectiveness of BMP implementation. This overall understanding can aid policy makers who have the difficult task of manufacturing the most suitable and efficient environmental protection programs.

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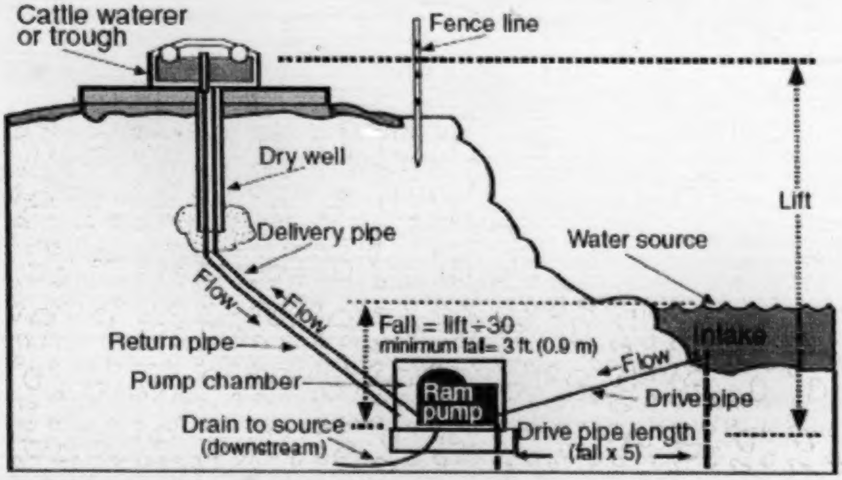
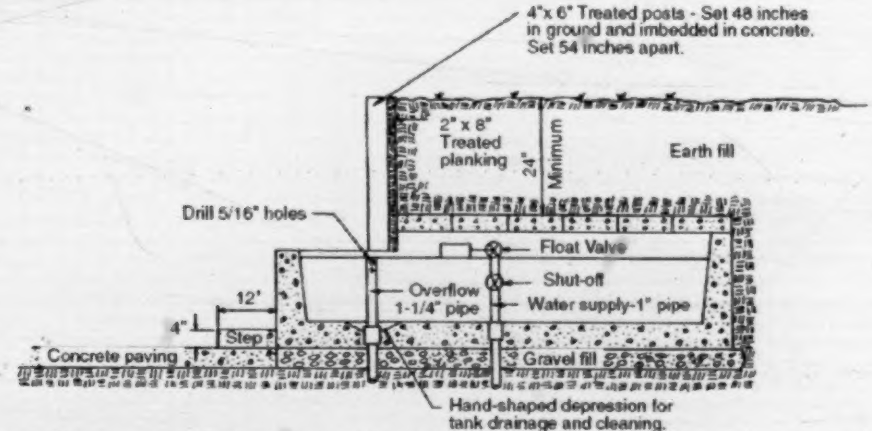
Appendix A: Examples of Off-Stream Watering Systems

Figure A.1 – A Ram Pump is used to take water from a water source and deliver is to upland areas


Cattle waterer or trough
Fence line
Dry well
Delivery pipe
Lift
Water source
Flow
Flow
Fall = lift ÷ 30
minimum fall= 3 ft (0.9 m)
Intake
Return pipe
Pump chamber
Ram pump
Flow
Drive pipe
Drain to source (downstream)
Drive pipe length (fall x 5)

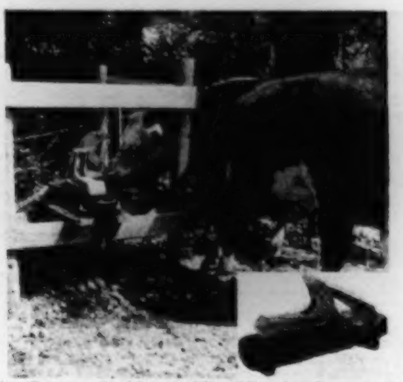
Source: Pfost, D. 2007. Pumps and Watering Systems for Managed Beef Grazing Systems. University of Missouri-Columbia. http://extension.missouri.edu/xplor/envqual/eq0380.htm (Last Accessed, April 22, 2008)

Figure A.2 – Pipes extending from an underground or open water source is pumped to a "freeze proof" tank where earth is used as insulation


4"x 6" Treated posts - Set 48 inches in ground and imbedded in concrete. Set 54 inches apart.
2" x 8" Treated planking
24" Minimum
Earth fill
Drill 5/16" holes
Float Valve
Shut-off
Overflow 1-1/4" pipe
Water supply-1" pipe
12"
4"
Step
Concrete paving
Gravel fill
Hand-shaped depression for tank drainage and cleaning.

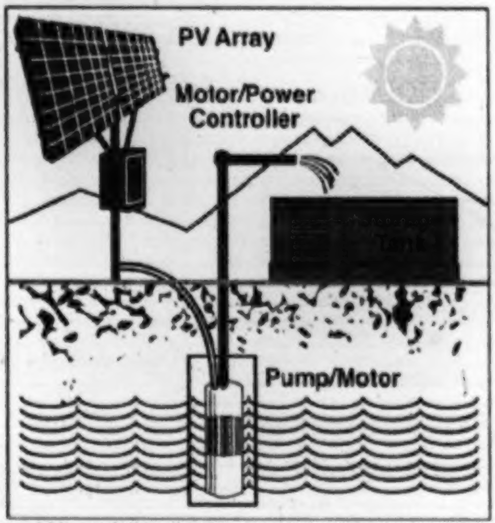
Source: Pfost, D. 2007. Pumps and Watering Systems for Managed Beef Grazing Systems. University of Missouri-Columbia. http://extension.missouri.edu/xplor/envqual/eq0380.htm (Last Accessed, April 22, 2008)

Figure A.3 – A nose pump use animal power to pump water from an underground well or open water source



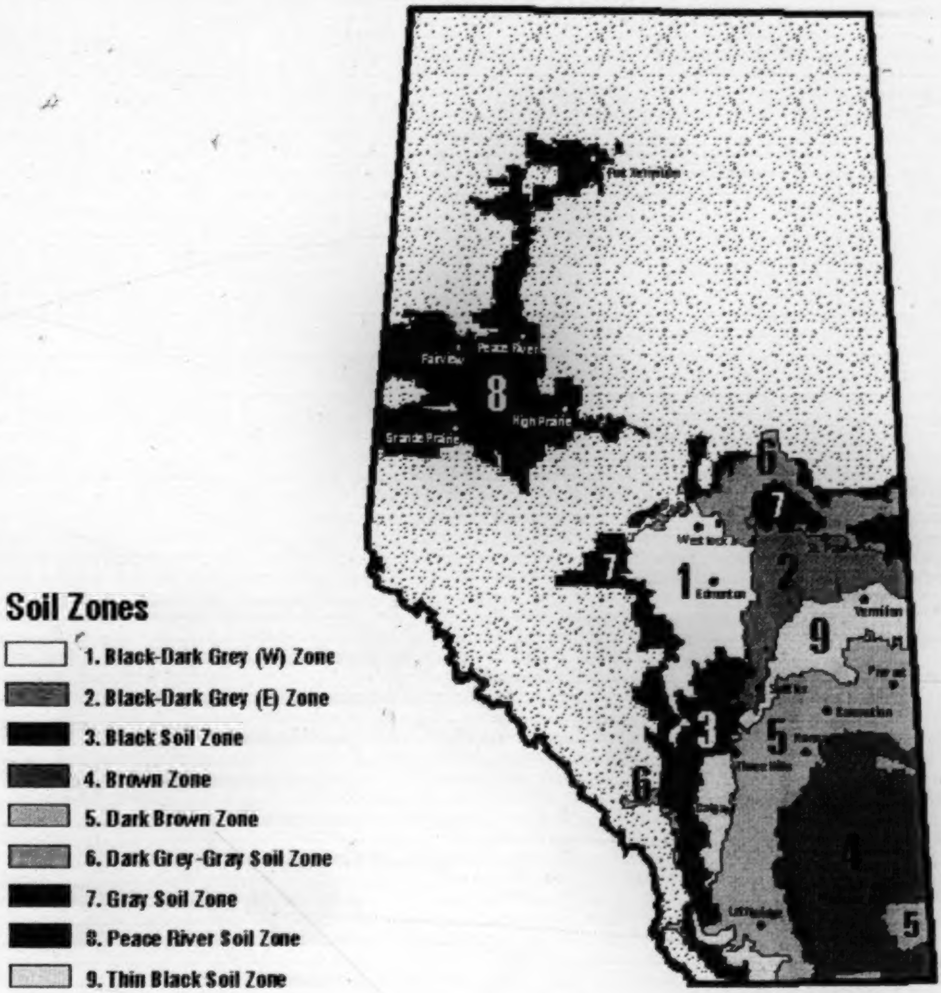
Source: Pfost, D. 2007. Pumps and Watering Systems for Managed Beef Grazing Systems. University of Missouri-Columbia. http://extension.missouri.edu/xplor/envqual/eq0380.htm (Last Accessed, April 22, 2008)

Figure A.4 – Solar off-stream watering system



Source: Morris, M. 2002. Solar-Powered Livestock Watering Systems. National Sustainable Agriculture Information Service. http://attra.ncat.org/attra-pub/solarlswater.html (Last Accessed, April 22, 2008)

Appendix B: Map of Alberta's Soil Zones


Fort Vermilion
Peace River
Fairview
8
High Prairie
Grande Prairie
6
7
Westlock
7
1
Edmonton
2
Vermilion
9
Provost
Coronation
3
5
Three Hills
6
4
Lethbridge
5
Soil Zones
1. Black-Dark Grey (W) Zone
2. Black-Dark Grey (E) Zone
3. Black Soil Zone
4. Brown Zone
5. Dark Brown Zone
6. Dark Grey-Gray Soil Zone
7. Gray Soil Zone
8. Peace River Soil Zone
9. Thin Black Soil Zone

Source: Alberta Agriculture and Rural Development (AARD). 2007. Farmer Reported Variety Yields.
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2647#zones
(Last Accessed, June 1, 2008)

Appendix C: Machinery Complement

Power Equipment	Size	Specifics
Tractor 1	250-299 hp	
Tractor 2	200-249 hp	
Tractor 3	150-259 hp	
Combine	300-400 hp	
Swather 1	36 ft	
Swather 2	25 ft	
Truck 1	565 hp	Semi with trailer
Truck 2	565 hp	Grain truck
Truck 3	565 hp	Cattleliner

Drawn Equipment	Size
Seeder	40 ft
Sprayer	90 ft
Cultivator	35 ft
Breaking Disc	15 ft
Feed Wagon	1000 cuft
Bale Processor	
Feed Mixer	
Scraper	
Forage Harvester	
2 Large Round Balers	
2 Bale Wagon	

Appendix D: Machinery Replacement Strategies

	Pros	Cons
Replace Key Machinery Frequently	-Reduces risk of breakdowns and costly repairs by replacing machinery every few years -Costly repairs may be covered by warranty -Less investment needed in maintenance tools & facilities -Farms with large land base needs reliable, efficient equipment	-High cost over the long of buying or leasing new equipment every few years
Replace Some Piece of Equipment Yearly	-Keeps machinery costs relatively constant from year to year -Avoids having to make a large cash outlay in any given year	-Could results in replacing machinery before it is really necessary
Replace When Cash Available	-Keeps machinery purchases from cutting into funds in bad years	-Hard to predict when extra cash will be available -Machinery may become very unreliable before cash is available
Keep It Forever	-May be the least-cost approach in the long run -Good for operators that can manage maintenance work	-Machinery may fail at very inopportune times -May be difficult to arrange financing on short notice -Operator must be willing to use old technology

Source: Edwards, W. 2005. Replacement Strategies for Farm Machinery. Iowa State Univeristy Extension, PM 180. http://www.extension.iastate.edu/Publications/PM1860.pdf (Last Accessed, April 22, 2008)

Appendix E: Summary of Tests of Distributional Best Fit

Chi-Squared Statistic

This is the best known goodness of fit test which can be used for both continuous and discrete sample data. The data is split into several bins and the statistic is defined as:

$$X^2 = \sum_{i=1}^{K} \frac{(N_i - E_i)^2}{E_i}$$

where

K = number of bins
N_i = the observed number of samples in the i^{th} bin
E_i = the expected number of samples in the i^{th} bin

A weakness of this test is that there are no clear guidelines for selecting the number of bins. @risk automatically picks and adjusts the bin size

Kolmogorov-Smirnov (K-S) Statistic

This test decides whether a sample comes from a hypothesized continuous distribution function. It is based on the empirical cumulative distribution function. Assuming a random sample $x_1,\ldots,x_n$ from some continuous distribution function, the empirical CDF is denoted by:

$$F_n(x) = \frac{1}{n} * [numberofobservations \le x].$$

The K-S statistic is based on the largest vertical difference between F(x) and $F_n(x)$ defined as:

$$D_n = \sup x|F_n(x) - F(x)|,$$

where n = total number of data points
F(x) = the fitted cumulative distribution function
$F_n(x)$ = the number of X_i's less than x, all divided by the number of data points

A weakness of this test is that it does not require binning making it less arbitrary than the chi-squared statistic. It also does not detect tail discrepancies very well, this statistic focuses on the middle of the distribution.

Anderson-Darling Statistic

This statistic is defined as:

$$A_n^2 = n \int_{-\infty}^{+\infty} [F_n(x) - F(x)]^2 \psi(x) f(x) dx$$

where

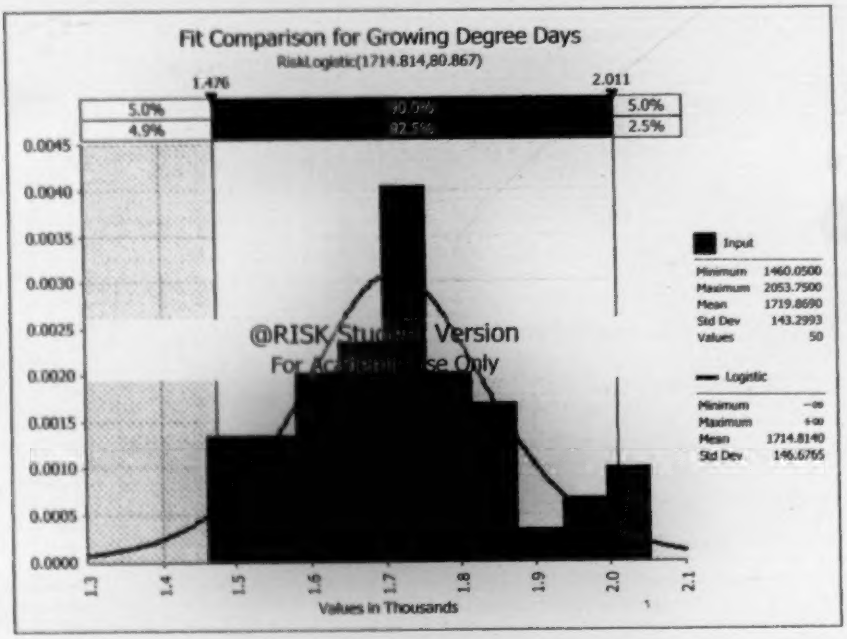
n = total number of data points

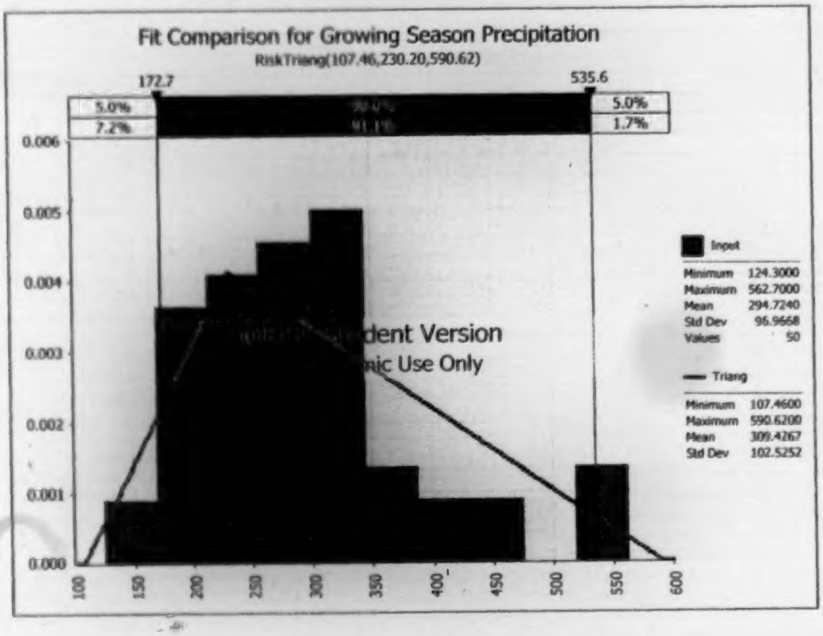
$$\psi^2 = \frac{1}{F(x)[1 - F(x)]}$$

f(x) = the hypothesized density function
F(x) = the hypothesized cumulative distribution function
$F_n(x)$ = the number of X_i's less than x, all divided by the number of data points

This statistics also does not require binning. It is different than the K-S test by highlighting the differences between the tails of the fitted distribution and input data.

Appendix F: Graphs of Distribution Fitting around Growing Degree Day and Growing Season Precipitation Datasets





Appendix G: Table of Cortus (2005) Standard Deviation Adjustment Comparisons by Crop

	Standard Deviation of Yield (tonne/ha)			
	Canola	**Barley**	**Flax**	**Wheat**
Marra-Schurle Factor	0.31	0.61	0.27	0.38
Simulation Model	0.37	0.71	0.27	0.58
%Difference	20%	17%	-1%	54%

Source: Cortus, 2005

Appendix H: Bushel to Tonne Conversion Factors

1 tonne of crop y = x bushels

Bushel Equivalent per tonne				
HRS	**Durum**	**Canola**	**Barley**	**Oats**
36.74	36.74	44.00	45.93	64.84

Source: Alberta Agriculture and Rural Development. 2008. Bushel/Tonne Converter.
http://www.agric.gov.ab.ca/app19/calc/crop/bushel2tonne.jsp#http://www.agric.gov.ab.ca/app19/calc/crop/bushel2tonne.jsp
(Last Accessed, April 22, 2008)

Appendix I: Soil Classifications

Soil classes indicate the limitations imposed by the soil in its use for mechanized agriculture. The subclasses indicate the kinds of limitations that individually or in combination with others, are affecting agricultural land use.

Classes	
Class	**Description**
1	Soils have no significant limitation in use of crops
2	Soils have moderate limitations that restrict the range of crops or require moderate conservation practices
3	Soils have moderately severe limitations that restrict the range of crops or require special conservation practices
4	Soils have severe limitations that restrict the range of crops or require special conservation practices.
5	Soils have very severe limitations that restrict their capability in producing perennial forage crops, and improvement practices are feasible.
6	Soils are capable only of producing perennial forage crops, and improvement practices are not feasible.
7	Soils have no capacity for arable culture or permanent pasture.
0	Organic Soils (not placed in capability classes).

Subclasses	
Subclass	**Description**
C	Adverse Climate
D	Undesirable soil structure and/or low permeability
E	Erosion
F	Low Fertility
I	Inundation by streams or lakes
M	Moisture limitation
N	Salinity
P	Stoniness
R	Consolidated bedrock
S	Combination of subclasses
T	Topography
W	Excess water
X	This Subclass is comprised of soils having a limitation resulting from the cumulative effect of two or more adverse characteristics

Appendix J: Fencing Cost Profile

BARB WIRE FENCE

Posts - All posts are six foot (180 cm) and have a spacing of 18 feet (5.5 m). This works out to 293 posts per mile (176 posts per km). We assume this length of fence will require 20 brace posts and nine corner and gate posts.
Wire - A roll of barbed wire is 1/4 mile (150 m) long. A three-wire fence one mile long requires 12 rolls and a four-wire fence one mile long requires 16 rolls. Two-strand standard 12.5-gauge barbed wire is used for the barbed wire fences.
Staples - One strand of barbed wire stretched one mile and attached to 293 posts requires approximately 4.3 lbs (2 kg) of staples. Therefore, a three-wire fence requires 13 lbs (6 kg) of staples and a four-wire all post fence requires approximately 18 lbs (8 kg) per mile.
Labour - Erection of fence, including corner posts, bracing, pounding posts, stretching and stapling wire, requires 70 hours per mile (42 hrs/km) for a three-wire barbed fence and 80 hours per mile (48 hrs/km) for a four-wire barbed fence.
Post Pounder - A team should be able to erect one mile of posts in 10 hours (one km in six hours)

Cost to erect barbwire fence ($/mile)	
Materials	**Four, standard barb, 2-strand, all post fence**
Line posts – 3-4 inch tops, 6 foot treated	$876.07
Brace posts – 4-5 inch tops, 8 foot, treated	$135.00
Corner and gate posts – 5-6 inch tops, 8 foot treated	$82.80
12.5 gauge, standard 2-strand barbed	$896.00
Staples, 1.5 inch	$19.98
Tractor, 50hp, total costs/hr (incl. fixed, repair, fuel and lube)	$247.32
Post pounder	$166.60
Labour	$880.00
Total	**$3,303.77**
$/metre	**$2.06**
$/foot	**$0.63**

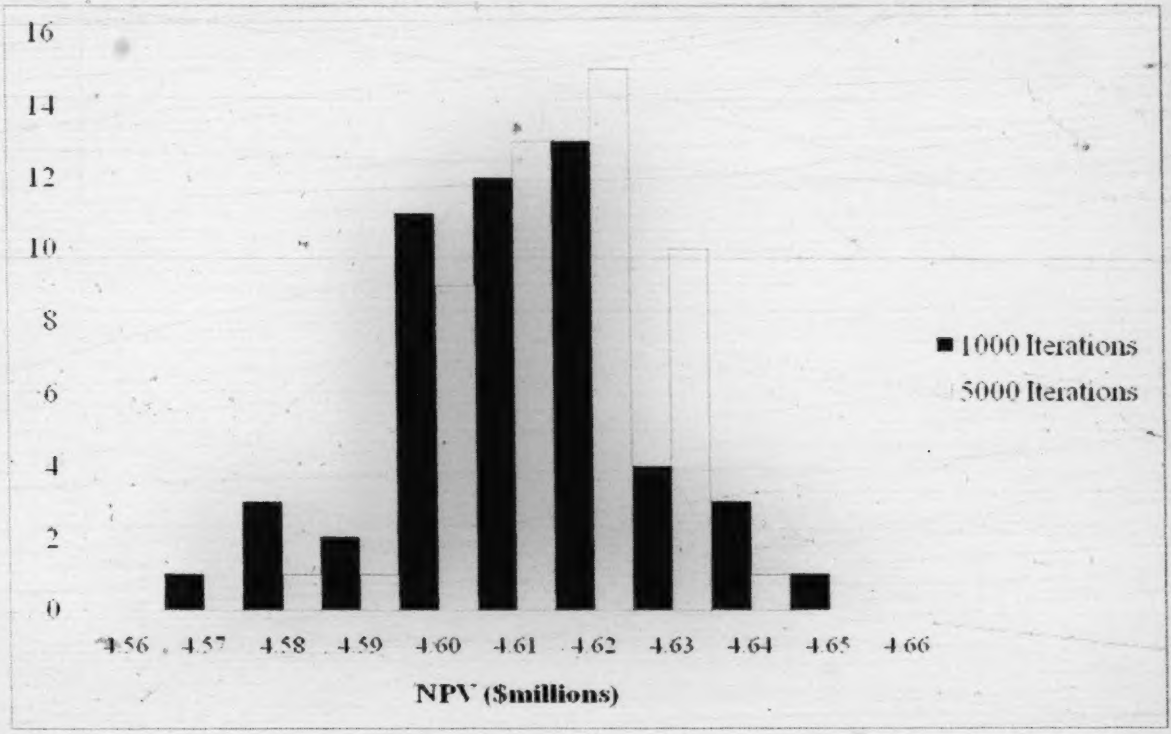
Source: Government of Saskatchewan http://www.agriculture.gov.sk.ca/Default.aspx?DN=c339823b-d410-4b8e-8987-46957c437d5a (Last Accessed, April 21, 2008)

Appendix K: Off-Stream Watering Cost Profile

Construction costs for dug-out and off-stream watering system, 500 AU's				
	Number	**Unit**	**Unit Price ($)**	**Total Cost ($)**
Stripping Topsoil	4,250	M^2	1	4,250
Excavation	3,450	M^3	3.5	12,075
Compacted Fill	2,940	M^3	1.5	4,410
Polyethylene Lining	2,900	M^2	1.1	3,190
Fencing	640	M	2.34	1,497.6
Wet Well Intake	1		5000	5,000
Miscellaneous	10	%		3,042.66
Total				**33,464.86**

Source: Ross, 2007

Appendix L: Distribution of 50 Simulations of the Representative Farm's 20 Year Gross Margin NPVs at 1000 and 5000 Iterations



Appendix M: Summary Statistics Tables

Table M.1 – Summary Statistics for the Reference Farm

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV	$ 4,607,467	$ 771.811	$ 7.016.648	$ 2.370.933	$ 6.120.217	$ 3.094.716
Crop Enterprise	$ 3.098.460	$ 722.466	$ 5,413.578	$ 1.035.647	$ 4.514.494	$ 1,682,425
Beef Enterprise	$ 1,173,295	$ 182.402	$ 1,776,111	$ 660.486	$ 1.530.804	$ 815.787
Perpetuity of NPV	$ 5.558.819	$ 2,013.609	$ 13.510.586	$ 691.230	$ 9.505.494	$ 1,612.145
Forage Sales	$ 45.333	$ 6.328	$ 72.057	$ 29.124	$ 57.735	$ 32.930
Year 1 Cash Flow	$ 572,161	$ 201.948	$ 1.485,223	$ 30.324	$ 967.979	$ 176.343
Year 2 Cash Flow	$ 536.951	$ 198.219	$ 1.414.136	$ 80.250	$ 925.461	$ 148.441
Year 3 Cash Flow	$ 558.412	$ 200.530	$ 1.276.749	$ 75.712	$ 951.451	$ 165.373
Year 4 Cash Flow	$ 538.877	$ 194.140	$ 1,259.944	$ 17.149	$ 919.391	$ 158.363
Year 5 Cash Flow	$ 528.675	$ 197.777	$ 1,194.655	$ 73.572	$ 916.318	$ 141,032
Year 6 Cash Flow	$ 516.609	$ 196.264	$ 1.199.496	$ 40.133	$ 901.286	$ 131.932
Year 7 Cash Flow	$ 523,546	$ 197.681	$ 1,243,571	$ 34.583	$ 911,000	$ 136,093
Year 8 Cash Flow	$ 485.424	$ 206.165	$ 1.164.943	$ 9.377	$ 889.506	$ 81,341
Year 9 Cash Flow	$ 572.975	$ 200.787	$ 1,264,354	$ 63.881	$ 966.517	$ 179,434
Year 10 Cash Flow	$ 555.170	$ 199.798	$ 1.252.933	$ 44.898	$ 946.774	$ 163,567
Year 11 Cash Flow	$ 577,327	$ 198.580	$ 1,449,033	$ 124.625	$ 966.544	$ 188,109
Year 12 Cash Flow	$ 554.214	$ 194.062	$ 1,330.967	$ 104.647	$ 934.576	$ 173.852
Year 13 Cash Flow	$ 530.319	$ 195.194	$ 1,265,045	-$ 18.956	$ 912.900	$ 147,739
Year 14 Cash Flow	$ 481,543	$ 183,919	$ 1,239,022	-$ 13.805	$ 842,025	$ 121,061
Year 15 Cash Flow	$ 514.846	$ 199.129	$ 1.137.124	$ 42.355	$ 905.140	$ 124,552
Year 16 Cash Flow	$ 572.675	$ 206.242	$ 1,485.223	$ 30.324	$ 976,910	$ 168,440
Year 17 Cash Flow	$ 537,956	$ 201,267	$ 1,414,136	$ 80,250	$ 932,440	$ 143,472
Year 18 Cash Flow	$ 557,049	$ 202.105	$ 1,276,749	$ 75.712	$ 953.174	$ 160,923
Year 19 Cash Flow	$ 538.112	$ 195,843	$ 1,259.944	$ 17.149	$ 921.964	$ 154,260
Year 20 Cash Flow	$ 526,913	$ 199.885	$ 1,194,655	$ 73,572	$ 918.688	$ 135,138
Grazing Season Days	301.53	11.48	330.69	276.66	324.03	279.02
Calf Weights (lbs)	577.52	18.95	625.64	536.50	614.65	540.38

Table M.2 – Summary statistics for representative with BMP #1 at the 25%, 50%, 75% and 100% protection level

	Mean	St Dev	Maximum	Minimum	95%	5%
Twenty Year NPV - 100%	$ 4,554,412	$ 752,541	$ 6,922,393	$ 2,372,574	$ 6,029,392	$ 3,079,431
75%	$ 4,567,213	$ 758,154	$ 6,947,074	$ 2,370,518	$ 6,053,195	$ 3,081,230
50%	$ 4,580,048	$ 763,814	$ 6,971,872	$ 2,368,428	$ 6,077,124	$ 3,082,972
25%	$ 4,592,876	$ 769,559	$ 6,996,626	$ 2,366,495	$ 6,101,212	$ 3,084,540
Crop Enterprise -100%	$ 3,049,043	$ 701,398	$ 5,315,915	$ 1,019,286	$ 4,423,783	$ 1,674,302
75%	$ 3,062,050	$ 707,466	$ 5,343,219	$ 1,017,945	$ 4,448,684	$ 1,675,416
50%	$ 3,075,083	$ 713,549	$ 5,370,648	$ 1,016,719	$ 4,473,639	$ 1,676,527
25%	$ 3,088,144	$ 719,655	$ 5,398,043	$ 1,015,717	$ 4,498,667	$ 1,677,620
Beef Enterprise - 100%	$ 1,172,404	$ 182,472	$ 1,775,932	$ 659,530	$ 1,530,050	$ 814,759
75%	$ 1,171,690	$ 182,464	$ 1,775,111	$ 658,848	$ 1,529,320	$ 1,675,416
50%	$ 1,170,950	$ 182,472	$ 1,774,289	$ 658,167	$ 1,528,594	$ 1,676,527
25%	$ 1,170,145	$ 182,527	$ 1,773,468	$ 657,485	$ 1,527,898	$ 1,677,620
Forage Sales - 100%	$ 51,161	$ 6,430	$ 78,088	$ 34,243	$ 63,765	$ 38,558
75%	$ 49,980	$ 6,434	$ 76,946	$ 33,039	$ 62,591	$ 37,369
50%	$ 48,799	$ 6,440	$ 75,802	$ 31,836	$ 61,422	$ 36,177
25%	$ 47,619	$ 6,448	$ 74,659	$ 30,598	$ 60,257	$ 34,981
Weaning Weights (lbs) - All Protection Levels	577.52	18.95	625.64	536.50	614.65	540.38
Growing Season Days - All Protection Levels	301.53	11.48	330.69	276.66	324.03	279.02

Table M.3 - Summary statistics for representative with BMP #2 at the 25%, 50%, 75% and 100% protection level

	Mean	St Dev	Maximum	Minimum	95%	5%
Twenty Year NPV - 100%	$ 4,514,978	$ 752,541	$ 6,882,959	$ 2,333,139	$ 5,989,958	$ 3,039,997
75%	$ 4,537,637	$ 758,154	$ 6,917,498	$ 2,340,943	$ 6,023,620	$ 3,051,655
50%	$ 4,560,331	$ 763,814	$ 6,952,155	$ 2,348,711	$ 6,057,407	$ 3,063,255
25%	$ 4,583,017	$ 769,559	$ 6,986,768	$ 2,356,636	$ 6,091,354	$ 3,074,681
Crop Enterprise -100%	$ 3,049,043	$ 701,398	$ 5,315,915	$ 1,019,286	$ 4,423,783	$ 1,674,302
75%	$ 3,062,050	$ 707,466	$ 5,343,219	$ 1,017,945	$ 4,448,684	$ 1,675,416
50%	$ 3,075,083	$ 713,549	$ 5,370,648	$ 1,016,719	$ 4,473,639	$ 1,676,527
25%	$ 3,088,144	$ 719,655	$ 5,398,043	$ 1,015,717	$ 4,498,667	$ 1,677,620
Beef Enterprise - 100%	$ 1,172,404	$ 182,472	$ 1,775,932	$ 659,530	$ 1,530,050	$ 814,759
75%	$ 1,171,690	$ 182,464	$ 1,775,111	$ 658,848	$ 1,529,320	$ 1,675,416
50%	$ 1,170,950	$ 182,472	$ 1,774,289	$ 658,167	$ 1,528,594	$ 1,676,527
25%	$ 1,170,145	$ 182,527	$ 1,773,468	$ 657,485	$ 1,527,898	$ 1,677,620
Forage Sales - 100%	$ 51,161	$ 6,430	$ 78,088	$ 34,243	$ 63,765	$ 38,558
75%	$ 49,980	$ 6,434	$ 76,946	$ 33,039	$ 62,591	$ 37,369
50%	$ 48,799	$ 6,440	$ 75,802	$ 31,836	$ 61,422	$ 36,177
25%	$ 47,619	$ 6,448	$ 74,659	$ 30,598	$ 60,257	$ 34,981
Weaning Weights (lbs) - All Protection Levels	577.52	18.95	625.64	536.50	614.65	540.38
Growing Season Days - All Protection Levels	301.53	11.48	330.69	276.66	324.03	279.02

Table M.4 - Summary statistics for representative with BMP #3 at the 25%, 50%, 75% and 100% protection level

	Mean	St Dev	Maximum	Minimum	95%	5%
Twenty Year NPV - 100%	$ 4,407,345	$ 746,596	$ 6,738,936	$ 2,240,274	$ 5,870,673	$ 2,944,018
75%	$ 4,457,935	$ 752,800	$ 6,809,738	$ 2,273,191	$ 5,933,423	$ 2,982,447
50%	$ 4,508,739	$ 759,258	$ 6,880,792	$ 2,305,816	$ 5,996,885	$ 3,020,592
25%	$ 4,559,341	$ 765,427	$ 6,951,542	$ 2,338,724	$ 6,059,579	$ 3,059,104
Crop Enterprise -100%	$ 2,936,455	$ 695,033	$ 5,175,495	$ 944,499	$ 4,298,719	$ 1,574,191
75%	$ 2,977,174	$ 701,901	$ 5,235,245	$ 967,320	$ 4,352,900	$ 1,601,449
50%	$ 3,017,900	$ 708,761	$ 5,295,237	$ 990,201	$ 4,407,071	$ 1,628,728
25%	$ 3,058,641	$ 715,624	$ 5,354,934	$ 1,013,325	$ 4,461,263	$ 1,656,019
Beef Enterprise - 100%	$ 1,170,497	$ 182,945	$ 1,770,548	$ 657,120	$ 1,529,069	$ 811,924
75%	$ 1,171,551	$ 182,790	$ 1,772,602	$ 658,432	$ 1,529,818	$ 1,601,449
50%	$ 1,172,776	$ 182,571	$ 1,774,666	$ 659,752	$ 1,530,615	$ 1,628,728
25%	$ 1,173,748	$ 182,503	$ 1,776,740	$ 661,079	$ 1,531,454	$ 1,656,019
Forage Sales - 100%	$ 42,699	$ 6,058	$ 68,364	$ 27,107	$ 54,573	$ 30,826
75%	$ 43,361	$ 6,126	$ 69,297	$ 27,628	$ 55,367	$ 31,355
50%	$ 44,022	$ 6,193	$ 70,215	$ 28,147	$ 56,161	$ 31,884
25%	$ 44,684	$ 6,261	$ 71,149	$ 28,641	$ 56,955	$ 32,413
Weaning Weights (lbs) - 100%	575.23	18.95	623.35	534.21	612.36	538.09
75%	575.87	18.95	623.99	534.84	613.00	538.73
50%	576.51	18.95	624.63	535.48	613.64	539.37
25%	577.15	18.95	625.27	536.12	614.28	540.01
Growing Season Days - 100%	300.14	11.48	329.30	275.28	322.64	277.63
75%	300.52	11.48	329.69	275.66	323.03	278.02
50%	300.91	11.48	330.08	276.05	323.42	278.41
25%	301.30	11.48	330.46	276.44	323.81	278.79

Table M.5 - Summary statistics for representative with BMP #4

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Twenty Year NPV	$ 4,574,633	$ 771,811	$ 6,983,814	$ 2,338,099	$ 6,087,383	$ 3,061,882
Crop Enterprise	$ 3,098,460	$ 722,466	$ 5,413,578	$ 1,035,647	$ 4,514,494	$ 1,682,425
Beef Enterprise	$ 1,173,295	$ 182,402	$ 1,776,111	$ 660,486	$ 1,530,804	$ 815,787
Forage Sales	$ 45,333	$ 6,328	$ 72,057	$ 29,124	$ 57,735	$ 32,930
Weaning Weights (lbs)	577.52	18.95	625.64	536.50	614.65	540.38
Grazing Season Days	301.53	11.48	330.69	276.66	324.03	279.02

Table M.6 - Summary statistics for representative with BMP #5 at the 25%, 50%, 75% and 100% protection level

	Mean	St Dev	Maximum	Minimum	95%	5%
Twenty Year NPV - 100%	$ 4,352,111	$ 771,811	$ 6,761,293	$ 2,115,578	$ 5,864,862	$ 2,839,361
75%	$ 4,407,742	$ 771,811	$ 6,816,924	$ 2,171,208	$ 5,920,492	$ 2,894,991
50%	$ 4,463,372	$ 771,811	$ 6,872,554	$ 2,226,838	$ 5,976,122	$ 2,950,622
25%	$ 4,519,002	$ 771,811	$ 6,928,184	$ 2,282,469	$ 6,031,753	$ 3,006,252
Crop Enterprise -100%	$ 3,098,460	$ 722,466	$ 5,413,578	$ 1,035,647	$ 4,514,494	$ 1,682,425
75%	$ 3,098,460	$ 722,466	$ 5,413,578	$ 1,035,647	$ 4,514,494	$ 1,682,425
50%	$ 3,098,460	$ 722,466	$ 5,413,578	$ 1,035,647	$ 4,514,494	$ 1,682,425
25%	$ 3,098,460	$ 722,466	$ 5,413,578	$ 1,035,647	$ 4,514,494	$ 1,682,425
Beef Enterprise - 100%	$ 1,173,295	$ 182,402	$ 1,776,111	$ 660,486	$ 1,530,804	$ 815,787
75%	$ 1,173,295	$ 182,402	$ 1,776,111	$ 660,486	$ 1,530,804	$ 1,682,425
50%	$ 1,173,295	$ 182,402	$ 1,776,111	$ 660,486	$ 1,530,804	$ 1,682,425
25%	$ 1,173,295	$ 182,402	$ 1,776,111	$ 660,486	$ 1,530,804	$ 1,682,425
Forage Sales - 100%	$ 45,333	$ 6,328	$ 72,057	$ 29,124	$ 57,735	$ 32,930
75%	$ 45,333	$ 6,328	$ 72,057	$ 29,124	$ 57,735	$ 32,930
50%	$ 45,333	$ 6,328	$ 72,057	$ 29,124	$ 57,735	$ 32,930
25%	$ 45,333	$ 6,328	$ 72,057	$ 29,124	$ 57,735	$ 32,930
Weaning Weights (lbs) - 100%	577.52	18.95	625.64	536.50	614.65	540.38
75%	577.52	18.95	625.64	536.50	614.65	540.38
50%	577.52	18.95	625.64	536.50	614.65	540.38
25%	577.52	18.95	625.64	536.50	614.65	540.38
Growing Season Days - 100%	301.53	11.48	330.69	276.66	324.03	279.02
75%	301.53	11.48	330.69	276.66	324.03	279.02
50%	301.53	11.48	330.69	276.66	324.03	279.02
25%	301.53	11.48	330.69	276.66	324.03	279.02

Table M.7 - Summary statistics for representative with BMP #6 at the 25%, 50%, 75% and 100% protection level

	Mean	St Dev	Maximum	Minimum	95%	5%
Twenty Year NPV - 100%	$ 4,287,273	$ 770,676	$ 6,731,347	$ 2,049,511	$ 5,797,798	$ 2,776,749
75%	$ 4,358,869	$ 771,017	$ 6,753,514	$ 2,121,741	$ 5,870,062	$ 2,847,675
50%	$ 4,430,717	$ 771,354	$ 6,830,389	$ 2,193,889	$ 5,942,571	$ 2,918,862
25%	$ 4,502,764	$ 771,807	$ 6,906,940	$ 2,265,854	$ 6,015,505	$ 2,990,022
Crop Enterprise -100%	$ 3,063,754	$ 721,488	$ 5,374,048	$ 993,712	$ 4,477,870	$ 1,649,638
75%	$ 3,072,557	$ 721,662	$ 5,383,799	$ 1,004,345	$ 4,487,015	$ 1,658,099
50%	$ 3,081,273	$ 721,893	$ 5,393,824	$ 1,014,729	$ 4,496,183	$ 1,666,363
25%	$ 3,089,910	$ 722,148	$ 5,403,554	$ 1,025,086	$ 4,505,321	$ 1,674,499
Beef Enterprise - 100%	$ 1,137,950	$ 181,373	$ 1,723,748	$ 622,613	$ 1,493,441	$ 782,458
75%	$ 1,146,397	$ 181,974	$ 1,736,839	$ 632,081	$ 1,503,065	$ 1,658,099
50%	$ 1,155,196	$ 182,532	$ 1,749,929	$ 641,549	$ 1,512,959	$ 1,666,363
25%	$ 1,164,266	$ 182,670	$ 1,763,020	$ 651,017	$ 1,522,298	$ 1,674,499
Forage Sales - 100%	$ 43,975	$ 6,276	$ 70,473	$ 27,693	$ 56,276	$ 31,675
75%	$ 44,320	$ 6,288	$ 70,874	$ 28,071	$ 56,644	$ 31,996
50%	$ 44,661	$ 6,301	$ 71,265	$ 28,448	$ 57,011	$ 32,311
25%	$ 44,999	$ 6,314	$ 71,667	$ 28,803	$ 57,375	$ 32,623
Weaning Weights (lbs) - 100%	566.23	18.47	613.13	526.24	602.42	530.03
75%	569.05	18.59	616.26	528.80	605.48	532.62
50%	571.87	18.71	619.38	531.37	608.54	535.21
25%	574.70	18.83	622.51	533.93	611.59	537.80
Growing Season Days - 100%	294.68	11.19	323.11	270.45	316.62	272.75
75%	296.39	11.26	325.00	272.00	318.47	274.31
50%	298.10	11.34	326.90	273.56	320.33	275.88
25%	299.82	11.41	328.80	275.11	322.18	277.45

Table M.8 - Summary statistics for representative with BMP #4 with 1%, 2%, 3%, 5% and 10% increases in calf daily weight gain

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,585,216	$ 769,473	$ 7,002,251	$ 2,352,978	$ 6,093,384	$ 3,077,048
2%	$ 4,595,289	$ 766,555	$ 7,020,687	$ 2,367,858	$ 6,097,737	$ 3,092,841
3%	$ 4,605,896	$ 765,325	$ 7,039,124	$ 2,382,737	$ 6,105,933	$ 3,105,860
5%	$ 4,624,491	$ 762,464	$ 7,034,516	$ 2,412,496	$ 6,118,920	$ 3,130,063
10%	$ 4,666,818	$ 769,195	$ 7,124,970	$ 2,426,937	$ 6,174,440	$ 3,159,197
Crop Enterprise - 1%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
2%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
3%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
5%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
10%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
Beef Enterprise - 1%	$ 1,184,500	$ 180,428	$ 1,797,042	$ 674,656	$ 1,538,139	$ 830,861
2%	$ 1,195,267	$ 177,681	$ 1,762,011	$ 650,528	$ 1,543,522	$ 847,012
3%	$ 1,206,670	$ 177,401	$ 1,783,000	$ 664,373	$ 1,554,375	$ 858,964
5%	$ 1,226,667	$ 175,928	$ 1,776,979	$ 692,063	$ 1,571,485	$ 881,848
10%	$ 1,272,293	$ 180,277	$ 1,836,525	$ 741,694	$ 1,625,635	$ 918,951
Forage Sales - 1%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
2%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
3%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
5%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
10%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
Weaning Weights (lbs) - 1%	582.49	19.14	631.10	541.06	620.00	544.99
2%	587.47	19.33	636.55	545.63	625.35	549.59
3%	592.44	19.51	642.01	550.19	630.69	554.20
5%	602.39	19.89	652.92	559.32	641.39	563.40
10%	627.27	20.84	680.20	582.15	668.12	586.42
Grazing Season Days - 1%	301.53	11.48	330.69	276.66	324.03	279.02
2%	301.53	11.48	330.69	276.66	324.03	279.02
3%	301.53	11.48	330.69	276.66	324.03	279.02
5%	301.53	11.48	330.69	276.66	324.03	279.02
10%	301.53	11.48	330.69	276.66	324.03	279.02

Table M.9 - Summary statistics for representative with BMP #5 with 1%, 2%, 3%, 5% and 10% increases in calf daily weight gain at the 100% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,362,695	$ 769,473	$ 6,779,730	$ 2,130,457	$ 5,870,863	$ 2,854,527
2%	$ 4,372,768	$ 766,555	$ 6,798,166	$ 2,145,337	$ 5,875,216	$ 2,870,320
3%	$ 4,383,375	$ 765,325	$ 6,816,602	$ 2,160,216	$ 5,883,412	$ 2,883,339
5%	$ 4,401,970	$ 762,464	$ 6,811,994	$ 2,189,975	$ 5,896,398	$ 2,907,541
10%	$ 4,444,297	$ 769,195	$ 6,902,449	$ 2,204,416	$ 5,951,918	$ 2,936,676
Crop Enterprise - 1%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
2%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
3%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
5%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
10%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
Beef Enterprise - 1%	$ 1,184,500	$ 180,428	$ 1,797,042	$ 674,656	$ 1,538,139	$ 830,861
2%	$ 1,195,267	$ 177,681	$ 1,762,011	$ 650,528	$ 1,543,522	$ 847,012
3%	$ 1,206,670	$ 177,401	$ 1,783,000	$ 664,373	$ 1,554,375	$ 858,964
5%	$ 1,226,667	$ 175,928	$ 1,776,979	$ 692,063	$ 1,571,485	$ 881,848
10%	$ 1,272,293	$ 180,277	$ 1,836,525	$ 741,694	$ 1,625,635	$ 918,951
Forage Sales - 1%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
2%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
3%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
5%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
10%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
Weaning Weights (lbs) - 1%	582.49	19.14	631.10	541.06	620.00	544.99
2%	587.47	19.33	636.55	545.63	625.35	549.59
3%	592.44	19.51	642.01	550.19	630.69	554.20
5%	602.39	19.89	652.92	559.32	641.39	563.40
10%	627.27	20.84	680.20	582.15	668.12	586.42
Grazing Season Days - 1%	301.53	11.48	330.69	276.66	324.03	279.02
2%	301.53	11.48	330.69	276.66	324.03	279.02
3%	301.53	11.48	330.69	276.66	324.03	279.02
5%	301.53	11.48	330.69	276.66	324.03	279.02
10%	301.53	11.48	330.69	276.66	324.03	279.02

Table M.10 - Summary statistics for representative with BMP #5 with 1%, 2%, 3%, 5% and 10% increases in calf daily weight gain at the 25% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,529,586	$ 769,473	$ 6,946,620	$ 2,297,348	$ 6,037,754	$ 3,021,418
2%	$ 4,539,659	$ 766,555	$ 6,965,057	$ 2,312,228	$ 6,042,107	$ 3,037,211
3%	$ 4,550,266	$ 765,325	$ 6,983,493	$ 2,327,107	$ 6,050,303	$ 3,050,230
5%	$ 4,568,861	$ 762,464	$ 6,978,885	$ 2,356,866	$ 6,063,289	$ 3,074,432
10%	$ 4,611,188	$ 769,195	$ 7,069,340	$ 2,371,307	$ 6,118,809	$ 3,103,567
Crop Enterprise - 1%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
2%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
3%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
5%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
10%	$ 3,098,696	$ 722,254	$ 5,413,578	$ 1,040,657	$ 4,514,313	$ 1,683,079
Beef Enterprise - 1%	$ 1,184,500	$ 180,428	$ 1,797,042	$ 674,656	$ 1,538,139	$ 830,861
2%	$ 1,195,267	$ 177,681	$ 1,762,011	$ 650,528	$ 1,543,522	$ 847,012
3%	$ 1,206,670	$ 177,401	$ 1,783,000	$ 664,373	$ 1,554,375	$ 858,964
5%	$ 1,226,667	$ 175,928	$ 1,776,979	$ 692,063	$ 1,571,485	$ 881,848
10%	$ 1,272,293	$ 180,277	$ 1,836,525	$ 741,694	$ 1,625,635	$ 918,951
Forage Sales - 1%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
2%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
3%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
5%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
10%	$ 45,342	$ 6,324	$ 72,057	$ 29,124	$ 57,736	$ 32,948
Weaning Weights (lbs) - 1%	582.49	19.14	631.10	541.06	620.00	544.99
2%	587.47	19.33	636.55	545.63	625.35	549.59
3%	592.44	19.51	642.01	550.19	630.69	554.20
5%	602.39	19.89	652.92	559.32	641.39	563.40
10%	627.27	20.84	680.20	582.15	668.12	586.42
Grazing Season Days - 1%	301.53	11.48	330.69	276.66	324.03	279.02
2%	301.53	11.48	330.69	276.66	324.03	279.02
3%	301.53	11.48	330.69	276.66	324.03	279.02
5%	301.53	11.48	330.69	276.66	324.03	279.02
10%	301.53	11.48	330.69	276.66	324.03	279.02

Table M.11 - Summary statistics for representative with BMP #6 with 1%, 2%, 3%, 5% and 10% increases in calf daily weight gain at the 100% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,299,332	$ 770,444	$ 6,694,985	$ 2,064,063	$ 5,809,402	$ 2,789,262
2%	$ 4,311,500	$ 769,843	$ 6,713,042	$ 2,078,615	$ 5,820,393	$ 2,802,607
3%	$ 4,322,345	$ 767,968	$ 6,731,099	$ 2,093,167	$ 5,827,561	$ 2,817,128
5%	$ 4,342,476	$ 763,639	$ 6,761,190	$ 2,122,270	$ 5,839,209	$ 2,845,743
10%	$ 4,385,347	$ 761,931	$ 6,815,092	$ 2,136,239	$ 5,878,732	$ 2,891,962
Crop Enterprise - 1%	$ 3,064,661	$ 720,907	$ 5,374,048	$ 998,740	$ 4,477,638	$ 1,651,683
2%	$ 3,064,661	$ 720,907	$ 5,374,048	$ 998,740	$ 4,477,638	$ 1,651,683
3%	$ 3,064,661	$ 720,907	$ 5,374,048	$ 998,740	$ 4,477,638	$ 1,651,683
5%	$ 3,064,661	$ 720,907	$ 5,374,048	$ 998,740	$ 4,477,638	$ 1,651,683
10%	$ 3,064,661	$ 720,907	$ 5,374,048	$ 998,740	$ 4,477,638	$ 1,651,683
Beef Enterprise - 1%	$ 1,149,975	$ 182,441	$ 1,744,232	$ 636,481	$ 1,507,560	$ 792,389
2%	$ 1,162,531	$ 182,219	$ 1,764,716	$ 650,349	$ 1,519,679	$ 805,382
3%	$ 1,173,981	$ 180,418	$ 1,764,023	$ 660,226	$ 1,527,600	$ 820,361
5%	$ 1,195,486	$ 177,111	$ 1,752,820	$ 653,409	$ 1,542,624	$ 848,348
10%	$ 1,241,790	$ 176,249	$ 1,811,315	$ 715,347	$ 1,587,237	$ 896,342
Forage Sales - 1%	$ 44,012	$ 6,266	$ 70,473	$ 27,876	$ 56,294	$ 31,730
2%	$ 44,012	$ 6,266	$ 70,473	$ 27,876	$ 56,294	$ 31,730
3%	$ 44,012	$ 6,266	$ 70,473	$ 27,876	$ 56,294	$ 31,730
5%	$ 44,012	$ 6,266	$ 70,473	$ 27,876	$ 56,294	$ 31,730
10%	$ 44,012	$ 6,266	$ 70,473	$ 27,876	$ 56,294	$ 31,730
Weaning Weights (lbs) - 1%	571.09	18.65	618.46	530.70	607.64	534.53
2%	575.95	18.84	623.79	535.17	612.87	539.03
3%	580.81	19.02	629.12	539.63	618.09	543.53
5%	590.54	19.39	639.79	548.55	628.54	552.53
10%	614.85	20.31	666.44	570.86	654.66	575.03
Grazing Season Days - 1%	294.68	11.19	323.11	270.45	316.62	272.75
2%	294.68	11.19	323.11	270.45	316.62	272.75
3%	294.68	11.19	323.11	270.45	316.62	272.75
5%	294.68	11.19	323.11	270.45	316.62	272.75
10%	294.68	11.19	323.11	270.45	316.62	272.75

Table M.12 - Summary statistics for representative with BMP #6 with 1%, 2%, 3%, 5% and 10% increases in calf daily weight gain at the 25% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,514,053	$ 770,131	$ 6,925,281	$ 2,280,652	$ 6,023,511	$ 3,004,596
2%	$ 4,524,752	$ 767,602	$ 6,943,623	$ 2,295,449	$ 6,029,252	$ 3,020,252
3%	$ 4,534,669	$ 765,436	$ 6,961,964	$ 2,310,247	$ 6,034,925	$ 3,034,414
5%	$ 4,554,788	$ 763,182	$ 6,957,356	$ 2,339,842	$ 6,050,625	$ 3,058,951
10%	$ 4,596,524	$ 766,970	$ 7,047,346	$ 2,354,165	$ 6,099,786	$ 3,093,263
Crop Enterprise - 1%	$ 3,090,267	$ 721,846	$ 5,403,554	$ 1,030,425	$ 4,505,085	$ 1,675,449
2%	$ 3,090,267	$ 721,846	$ 5,403,554	$ 1,030,425	$ 4,505,085	$ 1,675,449
3%	$ 3,090,267	$ 721,846	$ 5,403,554	$ 1,030,425	$ 4,505,085	$ 1,675,449
5%	$ 3,090,267	$ 721,846	$ 5,403,554	$ 1,030,425	$ 4,505,085	$ 1,675,449
10%	$ 3,090,267	$ 721,846	$ 5,403,554	$ 1,030,425	$ 4,505,085	$ 1,675,449
Beef Enterprise - 1%	$ 1,176,096	$ 180,893	$ 1,783,840	$ 665,113	$ 1,530,646	$ 821,545
2%	$ 1,187,558	$ 179,042	$ 1,748,587	$ 675,228	$ 1,538,480	$ 836,636
3%	$ 1,198,155	$ 177,199	$ 1,769,462	$ 654,857	$ 1,545,465	$ 850,845
5%	$ 1,219,777	$ 177,107	$ 1,763,812	$ 682,400	$ 1,566,907	$ 872,646
10%	$ 1,264,766	$ 178,835	$ 1,823,007	$ 731,748	$ 1,615,282	$ 914,250
Forage Sales - 1%	$ 45,013	$ 6,308	$ 71,667	$ 28,832	$ 57,377	$ 32,649
2%	$ 45,013	$ 6,308	$ 71,667	$ 28,832	$ 57,377	$ 32,649
3%	$ 45,013	$ 6,308	$ 71,667	$ 28,832	$ 57,377	$ 32,649
5%	$ 45,013	$ 6,308	$ 71,667	$ 28,832	$ 57,377	$ 32,649
10%	$ 45,013	$ 6,308	$ 71,667	$ 28,832	$ 57,377	$ 32,649
Weaning Weights (lbs) - 1%	579.64	19.01	627.94	538.47	616.91	542.37
2%	584.59	19.20	633.36	543.01	622.23	546.95
3%	589.54	19.39	638.79	547.55	627.54	551.53
5%	599.43	19.77	649.64	556.63	638.17	560.69
10%	624.16	20.71	676.76	579.33	664.75	583.57
Grazing Season Days - 1%	299.82	11.41	328.80	275.11	322.18	277.45
2%	299.82	11.41	328.80	275.11	322.18	277.45
3%	299.82	11.41	328.80	275.11	322.18	277.45
5%	299.82	11.41	328.80	275.11	322.18	277.45
10%	299.82	11.41	328.80	275.11	322.18	277.45

Table M.13 - Summary statistics for representative with BMP #4 with 3% and 6% pasture utilization increases

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,639,622	$ 768,489	$ 7,072,935	$ 2,410,391	$ 6,145,861	$ 3,133,383
2%	$ 4,702,618	$ 767,166	$ 7,131,010	$ 2,482,998	$ 6,206,262	$ 3,198,973
Crop Enterprise - 1%	$ 3,134,301	$ 724,092	$ 5,454,740	$ 1,071,170	$ 4,553,521	$ 1,715,081
2%	$ 3,170,058	$ 725,829	$ 5,496,136	$ 1,102,428	$ 4,592,683	$ 1,747,433
Beef Enterprise - 1%	$ 1,207,874	$ 177,392	$ 1,777,704	$ 667,617	$ 1,555,562	$ 860,186
2%	$ 1,240,288	$ 176,203	$ 1,787,100	$ 704,500	$ 1,585,646	$ 894,930
Forage Sales - 1%	$ 46,749	$ 6,390	$ 73,754	$ 30,343	$ 59,274	$ 34,225
2%	$ 48,163	$ 6,454	$ 75,452	$ 31,573	$ 60,813	$ 35,514
Weaning Weights (lbs) - 1%	589.69	19.47	639.15	547.53	627.86	551.53
2%	601.87	20.00	652.66	558.57	641.06	562.68
Grazing Season Days - 1%	308.91	11.80	338.88	283.35	332.04	285.78
2%	316.28	12.12	347.07	290.04	340.04	292.53

Table M.14 - Summary statistics for representative with BMP #5 with 3% and 6% pasture utilization increases at the 100% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,417,101	$ 768,489	$ 6,850,413	$ 2,187,870	$ 5,923,340	$ 2,910,862
2%	$ 4,480,096	$ 767,166	$ 6,908,488	$ 2,260,477	$ 5,983,741	$ 2,976,452
Crop Enterprise - 1%	$ 3,134,301	$ 724,092	$ 5,454,740	$ 1,071,170	$ 4,553,521	$ 1,715,081
2%	$ 3,170,058	$ 725,829	$ 5,496,136	$ 1,102,428	$ 4,592,683	$ 1,747,433
Beef Enterprise - 1%	$ 1,207,874	$ 177,392	$ 1,777,704	$ 667,617	$ 1,555,562	$ 860,186
2%	$ 1,240,288	$ 176,203	$ 1,787,100	$ 704,500	$ 1,585,646	$ 894,930
Forage Sales - 1%	$ 46,749	$ 6,390	$ 73,754	$ 30,343	$ 59,274	$ 34,225
2%	$ 48,163	$ 6,454	$ 75,452	$ 31,573	$ 60,813	$ 35,514
Weaning Weights (lbs) - 1%	589.69	19.47	639.15	547.53	627.86	551.53
2%	601.87	20.00	652.66	558.57	641.06	562.68
Grazing Season Days - 1%	308.91	11.80	338.88	283.35	332.04	285.78
2%	316.28	12.12	347.07	290.04	340.04	292.53

Table M.15 - Summary statistics for representative with BMP #5 with 3% and 6% pasture utilization increases at the 25% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,583,992	$ 768,489	$ 7,017,304	$ 2,354,761	$ 6,090,231	$ 3,077,753
2%	$ 4,646,987	$ 767,166	$ 7,075,379	$ 2,427,368	$ 6,150,632	$ 3,143,343
Crop Enterprise - 1%	$ 3,134,301	$ 724,092	$ 5,454,740	$ 1,071,170	$ 4,553,521	$ 1,715,081
2%	$ 3,170,058	$ 725,829	$ 5,496,136	$ 1,102,428	$ 4,592,683	$ 1,747,433
Beef Enterprise - 1%	$ 1,207,874	$ 177,392	$ 1,777,704	$ 667,617	$ 1,555,562	$ 860,186
2%	$ 1,240,288	$ 176,203	$ 1,787,100	$ 704,500	$ 1,585,646	$ 894,930
Forage Sales - 1%	$ 46,749	$ 6,390	$ 73,754	$ 30,343	$ 59,274	$ 34,225
2%	$ 48,163	$ 6,454	$ 75,452	$ 31,573	$ 60,813	$ 35,514
Weaning Weights (lbs) - 1%	589.69	19.47	639.15	547.53	627.86	551.53
2%	601.87	20.00	652.66	558.57	641.06	562.68
Grazing Season Days - 1%	308.91	11.80	338.88	283.35	332.04	285.78
2%	316.28	12.12	347.07	290.04	340.04	292.53

Table M.16 - Summary statistics for representative with BMP #6 with 3% and 6% pasture utilization increases at the 100% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,356,673	$ 771,700	$ 6,766,331	$ 2,122,025	$ 5,869,205	$ 2,844,142
2%	$ 4,421,728	$ 768,197	$ 6,855,725	$ 2,194,325	$ 5,927,394	$ 2,916,062
Crop Enterprise - 1%	$ 3,100,398	$ 722,540	$ 5,415,484	$ 1,038,402	$ 4,516,576	$ 1,684,220
2%	$ 3,136,214	$ 724,193	$ 5,456,914	$ 1,073,103	$ 4,555,632	$ 1,716,796
Beef Enterprise - 1%	$ 1,176,456	$ 181,621	$ 1,780,972	$ 664,194	$ 1,532,432	$ 820,480
2%	$ 1,211,123	$ 177,388	$ 1,782,591	$ 671,272	$ 1,558,803	$ 863,443
Forage Sales - 1%	$ 45,426	$ 6,332	$ 72,171	$ 29,199	$ 57,837	$ 33,015
2%	$ 46,841	$ 6,394	$ 73,869	$ 30,428	$ 59,375	$ 34,308
Weaning Weights (lbs) - 1%	578.40	18.99	626.64	537.28	615.63	541.18
2%	590.58	19.52	640.15	548.32	628.83	552.32
Grazing Season Days - 1%	302.06	11.51	331.30	277.14	324.62	279.50
2%	309.44	11.83	339.49	283.83	332.63	286.25

Table M.17 - Summary statistics for representative with BMP #6 with 3% and 6% pasture utilization increases at the 25% protection level

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1%	$ 4,568.758	$ 768.642	$ 6,996,339	$ 2,338,390	$ 6,075,296	$ 3,062,219
2%	$ 4,632.484	$ 767.367	$ 7,054,583	$ 2,410,745	$ 6,136,524	$ 3,128,444
Crop Enterprise - 1%	$ 3,125,847	$ 723.683	$ 5,444,984	$ 1,063,747	$ 4,544,267	$ 1,707,428
2%	$ 3,161,594	$ 725.425	$ 5,486,414	$ 1,095,039	$ 4,583,428	$ 1,739,761
Beef Enterprise - 1%	$ 1,199,871	$ 177.918	$ 1,764,508	$ 662,776	$ 1,548,591	$ 851,150
2%	$ 1,233,073	$ 176.765	$ 1,774,470	$ 699,176	$ 1,579,533	$ 886,614
Forage Sales - 1%	$ 46.419	$ 6.375	$ 73,353	$ 30,062	$ 58,915	$ 33,924
2%	$ 47,833	$ 6.439	$ 75.051	$ 31,282	$ 60,453	$ 35,212
Weaning Weights (lbs) - 1%	586.87	19.35	636.02	544.97	624.80	548.94
2%	599.05	19.88	649.53	556.01	638.01	560.09
Grazing Season Days - 1%	307.19	11.73	336.98	281.80	330.18	284.21
2%	314.57	12.05	345.17	288.49	338.19	290.96